THE BRIDGEWATER TREATISES

ON THE

POWER, WISDOM, AND GOODNESS OF GOD, AS MANIFESTED IN THE CREATION.

TREATISE II.

ON THE ADAPTATION OF EXTERNAL NATURE TO THE PHYSICAL CONDITION OF MAN.

BY J. KIDD, M.D.

THOU MADEST HIM TO HAVE DOMINION OVER THE WORKS OF THY HANDS ; THOU HAST PUT ALL THINGS UNDER HIS FEET.

PSALM VIII. 6.

ON THE

ADAPTATION OF EXTERNAL NATURE

TO THE

PHYSICAL CONDITION OF MAN,

PRINCIPALLY

WITH REFERENCE TO THE SUPPLY OF HIS WANTS, AND THE EXERCISE OF HIS INTELLECTUAL FACULTIES.

BY

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TO

HIS GRACE

THE ARCHBISHOP OF CANTERBURY.

MY LORD,

Having been appointed to write the following Treatise by the late President of the Royal Society, in consequence of your Grace's recommendation, it was natural that I should be desirous of publicly acknowledging the high honour thus conferred upon me.

I therefore request you to accept my respectful thanks for permitting me to inscribe this Treatise with your Grace's name: assuring you that, however inadequately I may have been found to answer your expectation in the execution, I have not applied myself to the task committed to me, without the exertion of much thought, and the strongest desire of so executing it, as to justify your Grace's favourable opinion.

I have the honour to be,

My Lord,

with the greatest respect,

Your Grace's most obliged

and obedient Servant,

J. Kidd.

Oxford, March 15, 1833.

PREFACE.

The occasion which gave rise to this and the accompanying Treatises is explained in the following notice: but the Author of the present Treatise thinks it right to add, that, although encouraged by the honour of having been recommended by His Grace the Archbishop of Canterbury, he should have shrunk from his present attempt, had he considered that any exact elucidation of the details of science was required in the execution of it.

As, however, the intention of Lord Bridgewater, and the very extent and diversified nature of the subject, seemed to him almost necessarily to exclude any great exactness of elucidation, and to require a popular rather than a scientific exposition of facts; and as the whole tenour of his pursuits during the last thirty years of his life accorded with the character of the proposed subject; he the more readily undertook a task, to the execution of which he could not but look forward with much pleasure. And if he should in any instance stimulate the reader to examine the question with any portion of the interest and satisfaction with which he has himself examined it, he is confident that he shall not have laboured in vain.

It will be for others to determine whether a judicious selection and a sufficiently natural arrangement of the materials of the following Treatise have been adopted: but to those, who may think that many of the subjects have been treated too cursorily, the Author begs leave to point out the extensive range afforded by so wide a field of inquiry; and the consequent necessity of compression in each particular; the subject of this Treatise being in fact an epitome of the subjects of almost all the others. He also considers it right to state, that it is the immediate object of the Treatise itself to unfold a train of facts, not to maintain an argument; to give a general view of the adaptation of the external world to the physical condition of man, not to attempt formally to convince the reader that this adaptation is a proof either of the existence and omnipotence of the Deity, or of his beneficence and wisdom; though undoubtedly it is hoped by the writer, as it was intended by the munificent individual who originally proposed the general subject of this and the

accompanying Treatises, that such a conviction, if not already existing, may be produced by its perusal. Without questioning, therefore, on the present occasion, the intellectual powers or the moral motives of those who profess themselves sceptics with respect to either natural or revealed religion, the Author addresses himself exclusively to those who are believers in both the one and the other. With respect indeed to a disbelief in the basis of natural religion, he must ever feel assured, as in another place he has expressed himself, that, however easy it may be to account for the external profession of a disbelief in God, the supposition of the existence of intellectual atheism involves an intellectual absurdity. With respect to the truth of Revelation, although the subject of this Treatise is not directly connected with that question, he would still wish to consider himself as addressing those only who with himself believe that the objects which surround us in our present state of existence, and which are so obviously intended to advance the general powers and faculties of *Man*, without advancing the powers and faculties of any other animal, are purposely destined to produce an ulterior and higher effect; the nature of which effect is to be learnt from the doctrines of Revelation alone. And he has thought it right to say thus much on the general subject of religion, not merely for the purpose of recording his own sentiments; but that, in professing to address those only who believe in revealed as well as in natural religion, if on any occasion he should assume the truth of Revelation, he may not be with justice accused of taking that for granted, of which the reader doubts.

NOTICE.

The series of Treatises, of which the present is one, is published under the following circumstances:

The Right Honourable and Reverend Francis Henry, Earl of Bridgewater, died in the month of February, 1829; and by his last Will and Testament, bearing date the 25th of February, 1825, he directed certain Trustees therein named to invest in the public funds the sum of Eight thousand pounds sterling; this sum, with the accruing dividends thereon, to be held at the disposal of the President, for the time being, of the Royal Society of London, to be paid to the person or persons nominated by him. The Testator further directed, that the person or persons selected by the said President should be appointed to write, print, and publish one thousand copies of a work *On the Power, Wisdom, and Goodness of God, as manifested in the Creation; illustrating such work by all reasonable arguments, as for instance the variety and formation of God's creatures in the animal, vegetable, and mineral kingdoms; the effect of digestion, and thereby of conversion; the construction of the hand of man, and an infinite variety of other arguments; as also by discoveries ancient and modern, in arts, sciences, and the whole extent of literature.* He desired, moreover, that the profits arising from the sale of the works so published should be paid to the authors of the works.

The late President of the Royal Society, Davies Gilbert, Esq. requested the assistance of his Grace the Archbishop of Canterbury and of the Bishop of London, in determining upon the best mode of carrying into effect the intentions of the Testator. Acting with their advice, and with the concurrence of a nobleman immediately connected with the deceased, Mr. Davies Gilbert appointed the following eight gentlemen to write separate Treatises on the different branches of the subject, as here stated:

THE REV. THOMAS CHALMERS, D. D.

PROFESSOR OF DIVINITY IN THE UNIVERSITY OF EDINBURGH.

ON THE ADAPTATION OF EXTERNAL NATURE TO THE MORAL AND INTELLECTUAL CONSTITUTION OF MAN.

JOHN KIDD, M. D. F. R. S.

REGIUS PROFESSOR OF MEDICINE IN THE UNIVERSITY OF OXFORD.

ON THE ADAPTATION OF EXTERNAL NATURE TO THE PHYSICAL CONDITION OF MAN.

THE REV. WILLIAM WHEWELL, M. A. F. R. S.

FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

ON ASTRONOMY AND GENERAL PHYSICS.

SIR CHARLES BELL, K. H. F. R. S.

THE HAND: ITS MECHANISM AND VITAL ENDOWMENTS AS EVINCING DESIGN.

PETER MARK ROGET, M. D.

FELLOW OF AND SECRETARY TO THE ROYAL SOCIETY.

ON ANIMAL AND VEGETABLE PHYSIOLOGY.

THE REV. WILLIAM BUCKLAND, D. D. F. R. S.

CANON OF CHRIST CHURCH, AND PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF OXFORD.

ON GEOLOGY AND MINERALOGY.

THE REV. WILLIAM KIRBY, M. A. F. R. S.

ON THE HISTORY, HABITS, AND INSTINCTS OF ANIMALS.

WILLIAM PROUT, M. D. F. R. S.

ON CHEMISTRY, METEOROLOGY, AND THE FUNCTION OF DIGESTION.

His Royal Highness the Duke of Sussex, President of the Royal Society, having desired that no unnecessary delay should take place in the publication of the above-mentioned treatises, they will appear at short intervals, as they are ready for publication.

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ON THE

ADAPTATION OF EXTERNAL NATURE

TO THE

PHYSICAL CONDITION OF MAN.

CHAPTER I.

INTRODUCTION.

Section I.

The Physical Condition of Man.

When Hamlet, in contemplating the grandeur of creation, breaks forth into that sublime apostrophe on man—"How noble in reason! how infinite in faculties! in form and moving, how express and admirable! in action, how like an angel! in apprehension, how like a God! the beauty of the world! the paragon of animals!"—who does not feel elated by the description? who does not feel conscious of its truth?

Nor is its truth the less admissible, because the poet, in concentrating the powers of his imagination on the excellences of that work of creation which bears the stamp of the Creator's image, has omitted to present to our view the reverse of the impression, the frailty namely of our fallen nature: for although, on moral and religious considerations, each individual is bound habitually to take the one view in conjunction with the other; in a simple philosophical contemplation of human nature we are not precluded by any reasonable barrier, from taking such a partial view of the subject as the occasion may suggest.

In the present instance, indeed, I am strictly called upon to consider, not the moral, but *the physical condition of man:* and to examine how far *the state of external nature is adapted* to that condition; whether we regard the provisions made for *the supply of man's wants, either natural or acquired;* or those which are made for *the*

exercise of his intellectual faculties. The following treatise naturally, therefore, divides itself into two parts: in the first of which it is intended to investigate and describe the physical condition of man; in the second, the adaptation of external nature to that condition.

But a wide field here opens to our view: for man cannot, under any circumstances, be considered as an insulated being; or unconnected with the rest of animated nature. He is indeed but one link in the great chain of animal creation; and not only does the contemplation of his condition lose half its interest, if separated from the contemplation of the condition of other animals; but it cannot be satisfactorily investigated without that aid. And, again, animal life itself is but one among many modes of existence, by which the Creator has manifested his omnipotence; and which it is necessary to contemplate in connexion with the general phenomena of nature, in order to show the superiority of that province, at the head of which human beings have been placed.

In attempting however to form a just estimate of the physical condition of man, we must not regard him merely under the aspect of savage or uncivilized life, and consider this as his natural state: for it may be presumed that, at the present day, such a puerile view of the question is not for a moment entertained by any one capable of philosophical reflection. In fact, in as many different states as man does actually exist, civilised or savage, so many are his natural states. If any indeed could be pre-eminently called his natural state, it would be that of civilization: for not only does experience show that his natural tendency is towards such a state; but we know, from the highest authority, that the existence of man is connected with a moral end; (with more indeed than a moral end; since morals have immediately a relation to this life only, while man is destined for a future;) and a moral end is hardly attainable in an uncivilized state of society.

Section II.

The general Constitution of external nature.

The more familiar objects of that external world by which man is surrounded are usually distributed into three kingdoms, as they are called; the *animal, vegetable,* and *mineral:* but for the purpose of this treatise it will be necessary to take into our account the phenomena of the *atmosphere* also.

The *atmosphere* principally consists of the *air* which we respire; (a form of matter so subtle, in all its states, as to be invisible;) together with a variable proportion of *water*, of which a part is always retained in close combination with the air; and, like the air itself, exists always in an invisible state. There are also diffused through

the atmosphere those still more subtle agents, *heat* and *electricity*. But all these, though of so subtle a substance, are in their occasional effects the most powerful agents of nature. For, omitting the consideration of their silent but wonderful operation, as exhibited in the process of vegetation, and in many other processes less open to observation, let us consider the occasional effects of air in the violence of a tornado; or of water, in the inundation of a rapid river: or let us contemplate the effect of either an indefinite diminution or increase of heat; on the one hand, the natural process of animal decomposition arrested by its abstraction, so that the imbedded mammoth remains at this moment in the same state that it was four thousand years ago; and in which, under the same circumstances, it undoubtedly would be, four thousand or four million years hence; on the other hand, the possibility of the dissipation of all the constituent parts of matter, or their fixation in the state of glass, resulting from the agency of indefinitely increased heat: or, lastly, let us consider the tremendous effects of condensed electricity in the form of lightning:—and we shall necessarily acknowledge that though in their usual state the constituents of the atmosphere are among the most tranquil agents of nature, yet, when their power is concentrated, they are the most awfully energetic.

In the *mineral kingdom* the most characteristic property of the several species appears to be a disposition to a pecular mode of mutual attraction among the particles composing the individuals belonging to them; from which attraction, when exerted under the most favourable circumstances, result that symmetry and regularity of form, to which the term *crystal* has been applied. The transparency and degree of hardness of crystals are various, and depend much upon external circumstances. The form is fundamentally the same for each species, though capable of being modified according to known laws; and the substance is chemically the same throughout its whole extent. Every atom of a crystallized mass of gypsum consists of water, lime, and sulphuric acid, united in the same proportions as are found to exist in the whole mass, or in any given part of it.

The individuals of the *vegetable kingdom* differ very remarkably from those of the mineral, both in form and substance. In their form we see nothing like the mathematical precision of crystallization; and in their substance they differ widely, according to the part of the vegetable which is examined: so that, independently of previous knowledge of the species, we could hardly discover any natural relation between the several constituent parts of the individual. What is there in the insulated leaf of a rose or of a peach tree, that would lead us to expect the fruit of the one or the flower of the other? But the most remarkable line of distinction between vegetables and the individuals of the preceding kingdom consists in their mode of increase and reproduction. Minerals can only increase, as such, by the apposition of particles specifically similar to themselves; and

can only be originally produced by the immediate combination of their constituent elements. But vegetables have an apparatus within them, by means of which they can assimilate the heterogeneous particles of the surrounding soil to their own nature; and they have also the power of producing individuals specifically the same as themselves: in common language, they are capable of contributing to their own growth, and to the continuation of their species. And as they produce these effects by means of internal organs adapted to the purpose, they are hence denominated organized bodies.

The individuals of the *animal kingdom* very closely resemble those of the vegetable in the two properties just described. The respective organs differ, as we might expect, in their form and position; but in their functions or mode of action there is a strong analogy, and even similarity, throughout. But animals differ from vegetables more remarkably than these do from every unorganized form of matter, in being endued with sensation and volition; properties which extend the sphere of their relations to such a degree, as to raise them immeasurable above all other forms of matter in the scale of existence.

In distributing the individuals of the material world among these four kingdoms of nature, there occasionally prevails considerable obscurity, not only with respect to the true place which an individual ought to occupy in the scale of a particular kingdom; but even with respect to the question, under which of the four kingdoms it ought to be arranged; this obscurity arising of course from the points of resemblance apparently balancing, or more than balancing, the points of difference. Let us for instance, in the atmospherical kingdom, take a fragment of a perfectly transparent crystal of pure ice; and, under ordinary circumstances, it would be difficult, either by the sight or the touch, to distinguish it from a fragment of transparent quartz, or rock crystal: indeed the transfer of the original term κρύσταλλος, from the one to the other, shows the close resemblance of the two. Some minerals again so nearly resemble vegetables in form, as to have given rise to specific terms of appellation, derived from the vegetable kingdom; as *flos ferri*, *mineral agaric*, &c. And, lastly, many of the animals called sea-anemones so far resemble the flower called by the same name, that their real character is at first very doubtful to those who are unacquainted with the animals of that genus. But, omitting these rare and equivocal instances, and avoiding the confinement of abstract definitions, we may safely affirm that, of all the kingdoms of nature, the individuals of the animal kingdom have the most extensive and important relations to the surrounding universe. And I need not here insist on the obvious inference, that if among the kingdoms of nature animals hold the first rank, in consequence of the importance of these relations, among animals themselves the first rank must be assigned to man.

CHAPTER II.

THE PHYSICAL CHARACTER OF MAN.

Section I.

The Physical Character of Man, compared with that of other Animals.

Although, when viewed in the aggregate of his faculties, moral as well as physical, man confessedly holds the first rank among animals; yet, if we exclude from our consideration those intellectual powers and moral qualities by which he is essentially characterised, and confine our view to his mere animal nature, we find that he scarcely differs in any important point from any of the species of the higher classes. In each there is the same necessity for air, and sleep, and food; and the nature of the food and the mode of its digestion are not materially different: the nutrient fluid extracted by the process of digestion is converted into blood of the same character, and distributed in the same manner through the system; the constituent parts of the body and their mode of growth are almost precisely the same; for the bone, muscle, tendon, skin, hair, and brain of the horse, or deer, or tiger, or bear, scarcely differ in their physical or chemical characters from the correspondent parts in man: similar secretions, as the bile, tears, and saliva, are separated by similarly constructed organs; and similar parts become similarly diseased: the special senses of sight, hearing, taste, and smell, are exercised through the medium of similar organs, simply modified according to the particular wants of individual species: the sources of mere bodily pain or pleasure are generally the same: the instinctive affections, passions, and propensities are the same, and are manifested in the same way; the angry look of a dog, for instance, bespeaking the internal feeling as strongly as that of the man; and the playful and rapid movements of the young puppy resembling the careless hilarity of childhood, no less than the stayed motions and wary eye of the aged hound resemble the sedateness of the aged human being.

Probably, however, it would be nearer the truth, were we to say that man, if divested of his intellectual powers, and endued merely with his animal nature, would be inferior to the brutes; for, possessing, as is the case, very few of the prospective or preservative instincts, he would be unable, without the aid of his intellectual powers, to provide for some of his most imperious wants.

But we may go even further than this. Let us suppose, for instance, a community of human individuals, who, though not gifted

with a sufficient degree of intellectual powers to instruct others, or improve themselves, were yet endued with them to a degree sufficient to render them, if the opportunity offered, docile to a certain extent, and capable of executing many of the common offices of life; (and what town or village does not present to our observation individual instances of such unhappy shadows of human nature?) how could a community like this exist; in which, though all, by the terms of the supposition, were capable of learning something, yet none would be capable of teaching anything? of what use under these circumstances would be that "instrument of instruments" the human hand, where there was no presiding mind to direct its movements? And, with respect to that wonderful auxiliary of the human powers, how incorrect is the reflection of those who have asserted that men are superior to brutes, only because they possess this instrument: and how truly philosophical is the opposite reflection, that man is not superior to other animals because he possesses this instrument; but he is provided with such an instrument precisely because he is already superior to all other animals. And the converse is equally true, that, with intellectual powers of even a higher order than those which they already possess, human beings could not live in a state of society, could hardly indeed exist in any state, unless furnished with such an instrument as the hand.

Section II.

Differences in the Form of the Infant and of the Adult; particularly with reference to the Spine.

And yet, notwithstanding the confessed superiority of man, if we view him only in the infancy of his individual existence, what is there that is calculated to give an earnest of his future vigour and activity, either with respect to bodily or mental powers; and what are all the advantages of the external world to a creature so utterly helpless, so utterly incapable of using or even passively enjoying them? In fact, with the exception of a very few instinctive rather than voluntary acts, such as that of deriving its nutriment from the mother's breast, the infant is, from the feebleness of its powers, incapable of efficient exertion; and depends entirely on the assistance of those around it.

The physical differences, observable in comparing the structure of the infant with that of the adult, which enable the one to execute many operations of which the other is incapable, exist to a certain extent in every part of the body; but are perhaps more remarkable in the spine than in any other part: and the spine therefore may be selected as a fit term of comparison.

In considering the office of the adult spine, with a view to the

present subject, we find that great strength, combined with great flexibility, is particularly requisite. With reference to strength, the pyramidal form of this natural column is obviously conducive to the purpose intended; and the arrangement of the solid matter, of which it is composed, is such as to contribute to the same effect; for that solid matter, instead of being collected into one compact mass, is diffused in such a manner as to resemble the structure of sponge; and it is well known, with reference to the strength of artificial columns, that, the same quantity of matter being given for each, and their height being the same, those columns which are hollow are stronger than those which are solid. Again, the whole column is made up of numerous parts, called vertebræ, which are so firmly bound together as to lessen the chance of being broken in the act of bending; and these vertebræ being applied to each other, throughout, by broad horizontal surfaces, are thus best calculated to support the perpendicular pressure of the superincumbent parts. The effect of general strength is further accomplished by the mutual locking in of the projecting portions, or processes, of the several vertebræ; and the same effect is accomplished to an additional extent among those vertebræ which belong to the thorax or chest, by the mode of articulation between them and the ribs; each rib being united, not entirely to a single vertebra, but partially to two contiguous vertebræ, near their line of junction.

The flexibility of the spine is secured to the utmost requisite extent, by the great number of articulations or joints which it possesses, amounting to more than twenty; as well as by the elasticity of the substance constituting those joints: and the projecting parts or processes of the several vertebræ, which serve for the insertion of the muscles and tendons which are to move the whole, are differently disposed in the neck, the back, and the loins; so as to be accommodated to the degree and kind of motion required in each: thus the vertebræ of the neck admit of a lateral motion to a greater extent than those of the back; and the vertebræ of the back admit of flexion and extension to a greater degree than those of the neck; while the vertebræ of the loins, being intended for support rather than flexibility, have their processes so distributed, as to contribute principally to the former of those effects.

Thus far we have considered the conditions of the adult spine, and have seen that they are calculated most admirably both for flexibility and for strength. Let us now examine the same column in the age of early infancy; and here we shall see, that, although at that period the parts, in which the conditions of strength and flexibility are so remarkably developed in the adult state, are not yet formed, or not completed; those parts which are essential to the security of the life of the individual are nearly in as perfect a state as at the age of manhood: so that in the midst of the most decided marks of weakness and imperfection in the rest of the column, there is an extraordinary instance of strength and perfect growth,

in precisely that part of it which could not have been left in an incomplete state, without manifest, immediate, and constant danger to the individual. In other words, the bodies and processes of the several vertebræ on which the strength and flexibility of the spine depend, are in early infancy still in a soft or cartilaginous state; while the annular portions, which with their intervening ligaments constitute the spinal canal, are completely ossified; so as to give as great a degree of security to the spinal marrow as at the age of manhood.

Nor need we spend much time in ascertaining the final cause of this remarkable difference. Is it not indeed obvious on a moment's reflection, that the very helplessness and imperfect state of the physical powers in infancy, so ill understood and appreciated, though so beautifully described by Lucretius, contribute to the fuller developement of the moral character, not only of the individual, but of his parents also, and of all his immediate connexions. The mutual affection, for instance, that takes place and is cemented between the infant and its mother, during the lengthened period in which the latter nurses her offspring; the stimulus, which is given to the exertions of the other parent in supplying the increasing wants of those who depend on him for support; and the general feeling and expression of good-will and attachment, which bind together the numerous individuals of the same family; all coincide to increase the sum of human happiness and virtue. Whereas, were the infant born with all its powers complete, and capable of exerting those powers as soon as born, independently of the assistance of parent, or sister, or brother; what would then remain of those endearing relations, but the empty name?

How incorrect then is the conclusion of the poet in that otherwise most beautiful passage of his poem! "The new-born babe, which like the shipwrecked mariner, lies prostrate on the ground, naked and destitute of every assistance required for the support of life, pierces the surrounding air with its incessant cries; as if foreseeing the long train of miseries which it must hereafter encounter. And yet the tender foal and lamb not only begin to crop the grass, but play about the mother almost as soon as born. The nurse's soothing lullaby is not wanted by them, nor the excitement of the rattle or of any other toy: nor do they require a change of dress accommodated to the changing temperature of the surrrounding atmosphere; nor arms for their defence, nor walled cities for their protection; kind nature supplying to them in bountiful profusion whatever is necessary to satisfy their wants."* As if it might not have been reasonably and safely concluded, that that same power, (call it "nature," or by any other name,) which provided so amply

* Tum porro Puer, ut sævis projectus ab undis
Navita, nudus humi jacet, infans, indigus omni
Vitali auxilio, cum primum in luminis oras
Nixibus ex alvo matris natura profudit;

for the early wants of the lower species of animals, had some good and special reason for leaving the human infant in a temporary state of helpless weakness.

Section III.

Physical Superiority of Man, on what Principle to be estimated.

From this helplessness in his early years, and from the occasional inferiority of some of his physical organs to the corresponding organs of brutes, it has sometimes been absurdly asked what claim man has, from his physical structure or powers, to be placed first in the scale of animal beings. His strength, what is it to that of the elephant or of the horse, or even of some species of reptiles or fish? his powers of sight and motion, what are they to those of the bird? his sense of odours, to that of the dog? his touch, to that of the spider?

And yet, even if we entirely omit the consideration of the soul, that immaterial and immortal principle which is for a time united to his body, and view him only in his merely animal character, man is still the most excellent of animals. How confined are the powers of other animals, considered generally, when compared with those of the human species. The comb of the bee indeed is in its construction wonderful; and so is even the nest of the bird, or the habitation of the beaver: but these animals could never be taught to fabricate, or to use, the simplest of those machines or instruments, which man, even in a very partially civilized state, is in the daily habit of making and employing: much less could they be taught to perform those complicated operations which result from their employment.

But, it may perhaps be said, it is the mind, the intellectual power of man, which enables him to produce the effects in question. His mind indeed enables him to conceive the plan of those operations which he executes, but it does no more: and were his form deficient by one of the smallest of its present members, he would be rendered nearly helpless. Take from his hand but one of the fingers, and he could do nothing. It is the human hand which gives the power of execution to the human mind; and it is the relative position of one of the fingers to the other four, which principally stamps the cha-

Vagituque locum lugubri complet, ut æquum 'st,
Cui tantum in vita restet transire malorum.
At variæ crescunt Pecudes, Armenta, Feræque;
Nec crepitacula eis opu' sunt, nec cuiquam adhibenda 'st
Almæ nutricis blanda atque infracta loquela:
Nec varias quærunt Vesteis pro tempore Cœli.
Denique non Armis opus est, non Mœnibus altis,
Queis sua tutentur, quando omnibus omnia large
Tellus ipsa parit, naturaque dædala rerum.
Lib. V. 223—235.

racter of the hand; for the thumb, by its capability of being brought into opposition with each of the other fingers, enables the hand to adapt itself to every shape; and gives it that complete dominion which it possesses over the various forms of matter.*

Give all the intelligence therefore that you please to the horse, or to the elephant, yet with hoofs instead of hands it is physically impossible that they could construct the simplest instrument: nor could the organs even of the beaver, were that animal gifted with the highest intellectual powers, enable it to effect much more than it is capable of effecting at present.

Man then is in every sense superior, in organization as well as in intellectual powers, to all other animals; and the degree of resemblance to him, as thus superior, is the main principle of classification adopted at the present day: and upon the whole it will be found that, in proportion as the powers and relations of animals are extensive, their structure resembles that of man. And, with respect to the degrees of this resemblance, it may be observed that occasionally it is so strong, as to constitute all but identity of form, as in some quadrumanous animals, or apes; while in others it is so faint, as to render it questionable whether we are viewing an animate or inanimate body, as in several varieties of sponge. It is evident that the stability of the principle of classification, now described, depends on the permanency of the specific form of animals: and it will be found that nature has guarded this point in so sacred a manner, that after the lapse of thousands of years, the identity of the species may be not only traced, but demonstrated, when nothing but the almost mouldering bones of the individual remain. But this subject will be considered more at large hereafter.

As then, in estimating the moral or intellectual characters of particular men, we are not influenced by the consideration of insulated defects or excellences, but of the aggregate powers and qualities of the individual; so, in comparing other animals with man, we ought not to affirm that they approach nearer to the standard of his perfection in proportion as they approach nearer to him in the structure of this or that part, or in the developement of particular powers or qualities; but in proportion to that approximation which results from the balance of their structure and powers considered collectively. And on this principle, however nearly a few of them may resemble him, they never can approach even the confines of an equality of nature; whatever some speculative individuals have presumptuously supposed, or others in their simplicity have feared. Thus the resemblance to the human form, as well internally as externally, is so remarkable in particular species of the ape, that while some philosophers (who however proceeded without a knowledge, or a due con-

* The term *poltroon*, if not of fancied etymology, (*pollice truncatus*,) verifies this statement; the Roman soldier who had been deprived of his thumb, being deemed unfit for service.

sideration of the true principles of the science concerned in their reasonings) have maintained that the ape and man are but varieties of the same species, or at most but different species of the same genus; others, with an unnecessary anxiety, have laboured to vindicate the supposed insult thus offered to the dignity of human nature, by searching for some fixed and invariable difference in the structure of the orresponding parts of each.

But the question is puerile: for let us even suppose that the whole and every part of the structure of the ape were the same as that of man; let every bone, and every muscle, and every fibre of the one correspond exactly with those of the other, not only in form and situation, but also in size and proportion; let the brain itself, that tangible instrument of the intellectual powers, be in structure the counterpart of the human; yet, unless in its functions it resembled that of man, in other words, unless there were associated with it his intellectual peculiarities and the moral and religious sense, to what dreaded conclusion would the closest resemblances lead? However near the approximation in their form, in their nature, there must ever be an immeasurable distance between the two. The ape, compared with man, may indeed be among other animals "proximus huic;" still however it must be added, "longo sed proximus intervallo."

Section IV.

Early and gradual Developement of the inellectual Faculties of Man.

The helplessness of infancy then is but temporary: and a new scene soon opens to the contemplation of those who have sufficient opportunities of watching the developement of the human character: for, long as is the period, compared with the natural term of his own life, and longer still, compared with the corresponding period in the life of other animals, before man attains the full stature of his mind as well as of his body; he at a very early season begins to manifest the superiority of his intellectual nature: he very soon begins to collect those materials for future use, which, though he will never hereafter be able to call to mind the moment or the circumstances of their accession, he will use as effectually as if he had originally acquired them by industrious and direct attention.

It does not fall within the intention of this treatise to attempt to ascertain the period when the first dawn of intelligence enlightens the countenance of the infant; but, undoubtedly, among its earliest beams are those expressive smiles, which, although they are occasioned by the aspect of the mother, and are perhaps only connected with the expectation of an animal pleasure, namely the simple enjoyment of nourishment, yet are soon elicited by other individuals

also, who may understand how to win the attention, and amuse the faculties of the infant mind.

It seems as if there were implanted in the young of all animals, of the higher orders, an instinctive propensity to those actions which are naturally determined by their specific form when fully developed; in order perhaps, among other purposes, to give occasion for that exercise of the limbs which is necessary to the health of the individual. Hence the young ram couches his head, and tilts his adversary, long before his horns have appeared; and the young pheasant assails his antagonist with his projected legs, long before his spurs have begun to bud. And, following this analogy, may we not reasonably suppose that the sports of childhood have a natural tendency to prefigure the occupations of manhood; and that by the extension of the same principle, independently of the impulse given by systematic education, or spontaneous imitation of their parents and others, there are instinctive differences in the amusements of children of different temperaments, connected with their future destinations in life? Thus while the boy is engaged in the mimicry of military parade or equestrian exercises, the girl devotes her time to more feminine occupations, and busies herself in acting the various duties which her nursery or household will hereafter require. The recorded attempt to conceal Achilles in female attire, whether founded in fact, or, as is probable, merely a fictitious anecdote, will serve to illustrate the present point; inasmuch as the use of the means, said to have been employed by Ulysses to detect the hero, was evidently suggested by the principle just now advanced.

At this early period of life then, the judgment being not sufficiently matured for deeper observation, the mind is satisfied with a view of the form and surface of objects presented to it; with their anatomy, as it were, rather than with their physiology: but, in the mean time, it is thus acquainting itself undistractedly with those sensible qualities with which it must necessarily be familiar before it can proceed to reason on causes and relations. And although it may appear at first view that a very disproportionately long period of our life is devoted to the mere exercise of the senses, it is yet highly probable that important mental operations may be simultaneously going on, though we are at the time unconscious of them: for something analogous is observable throughout the whole course of our existence. How few there are, for instance, who, at any period of life, can call to mind a tenth part of what they have even recently heard or observed. And if this may be correctly affirmed of the adult age of life, and of those individuals whose original powers of mind are great, how much more strongly will it apply to those whose original powers of mind are not above the common standard, or not yet matured by age. So that there can be very little doubt that the general principles and rules, which regulate the reasoning and conduct of men on ordinary occasions, have been originally deduced by each individual from much of what has been long forgotten.

It has been asserted by persons,* whose intellectual powers were of the highest order, and whose industry was as remarkable as their abilities, that more than six or eight hours in each day could not be employed effectively by the generality of young men for the purpose of mental improvement. If this however be the case, and as a general position it probably is not very far from the truth, in vain does the ambitious student rob nature of that sleep which Providence has made necessary for the renovation of the exhausted powers of our mind, as well as of our body; and in vain also does he attempt to combine simultaneously the efforts of mental attention with bodily exercise, or to pursue his severer studies during the hour of meals: in both which cases, they, who adopt the custom, not only err in employing too continuous an application of the powers of the mind; but in impeding to a certain and often very inconvenient degree the process of natural respiration; and consequently, of other functions of the body, particularly of digestion. How main a point ought it to be therefore with those who superintend the education of young persons, to avoid the application of too great a strain on the natural spring of the intellectual powers.

It is questionable whether at any period of life the correspondence between the external world and the sensitive and intellectual faculties of man, is so rapid, so vivid, and so effectual, as during that space which is intermediate to infancy and adolescence: and this fact, if it be so, may be explained by that principle of our nature, on which depends the love of novelty; namely, that susceptibility of the nerves which makes them capable of being stimulated more vehemently by new, than by accustomed impressions: for certainly this principle is likely to be more exercised in proportion as we are nearer the period of infancy; since every impression is then either absolutely new, or has not yet rendered the nerves dull by too frequent a repetition of its application. Another happy instance of the harmony that exists between the nature of man and the external world, is the readiness and confidence with which at this early period of life the impressions of sense are received. Where all is new, and therefore equally matter of wonder, there is yet no room for doubt. Nature teaches the mind to receive everything without distrust, and to rely implicitly on those inlets to knowledge, the impressions of sense, which are destined to be its only guides in the first years of life. Scepticism is not the tendency of childhood: and perhaps it is with reference to the analogy between the eye of faith and the eye of sense at this early period of life, that our Saviour pronounces a blessing upon those who receive the evidences of our religion with the simplicity of little children.

* Lord chief justice Hale; (see Boswell's Life of Johnson, vol. ii. p. 511. 4to. London, 1791;) not to mention living authorities.

CHAPTER III.

On the Powers of the human Hand, considered as a corporeal Organ.

At length however, having passed the preparatory discipline both of natural and of parental education, and having arrived at the maturity of his powers, man is fitted to exercise his empire over the external world.

But before we consider the character of the materials provided for the supply of his various wants, or for the exercise of his intellectual faculties, let us examine more closely than hitherto the condition of those corporeal organs, by the agency of which he is enabled to produce the results intended.

There can be no doubt that those organs are, if not exclusively, at least pre-eminently, the *brain* and the *hand:* of the latter of which, not only are the uses of the several parts and of the whole made practically manifest every moment of our lives; but its antecedent capabilities are so open to the investigating eye of reason, as to afford one of the readiest subjects of physical demonstration. And although, with respect to the brain, we not only have no satisfactory evidence, but cannot even form a probable conjecture, of the use or mode of action of any particular part; yet we cannot doubt that it is the instrument by which our intellectual powers hold communion with external nature. I shall dedicate therefore this and the following chapter to the consideration of the general history of these organs.

It would be an invasion of the province of others to give an anatomical description of the several constituent parts of the human hand: but in saying that its adaptation to the various purposes to which it is applicable is so open to the investigating eye of reason, as to afford one of the readiest subjects of physical demonstration, a tacit reference was made to that remarkable part of the writings of Galen, in which he expatiates upon the capabilities of this wonderful instrument: and that that extraordinary writer could hardly have selected a better subject, for the exercise of his powers in intellectual analysis, will be readily granted on a perusal of the following passages; provided they correctly represent the spirit of the original.

In that portion of his works which bears this title, "On the Use of the various Parts of the Body," after having defined what is to be understood by the term *part*, or *member*, as applied to an animal body, Galen proceeds in the following manner:* "But all these parts of the body were made for the use of the soul, that sentient and intelligent principle which animates the body, and of which the body is merely the organ; and on this account the component parts of

* Lib. I. cap. 2.

animals differ according to the nature of this principle: for some animals are bold and fierce; others are timid and gentle: some are gregarious, and co-operate for their mutual sustenance and defence; others are solitary, and avoid the society of their fellows: but all have a form or body accommodated to their natural dispositions and habits. Thus the lion has powerful fangs and claws; the hare has swiftness of foot, but in other points is defenceless. And the fitness of this arrangement is obvious: for those weapons with which the lion is furnished are as appropriate to his nature, as they would be useless to the timid hare; whose safety, depending entirely on flight, requires that swiftness of foot for which she is so remarkable. But to man, the only animal that partakes of divine intelligence, the Creator has given, in lieu of every other natural weapon or organ of defence, that instrument, *the hand;* an instrument applicable to every art and occasion, as well of peace as of war. Man therefore wants not a hoof, or horn, or any other natural weapon; inasmuch as he is able with his hand to grasp a much more effective weapon, the sword or spear. Besides which, natural weapons can be employed only in close conflict; while some of the weapons employed by man, as javelins or arrows, are even more effectual at a distance. And, again, though man may be inferior to the lion in swiftness, yet by his dexterity and skill he breaks in to his use a still swifter animal, the horse; mounted on whose back he can escape from or pursue the lion, or attack him at every advantage. He is enabled moreover by means of this instrument to clothe himself with armour of various kinds, or to entrench himself within camps or fenced cities. Whereas were his hands encumbered with any natural armour, he would be unable to employ them for the fabrication of those instruments and means, which give him such a decided advantage over all the other animals of creation.

"Nor have we yet enumerated the most important of those privileges which the hand imparts to man. With this he weaves the garment that protects him from the summer's heat, or winter's cold; with this he forms the various furniture of nets and snares, which give him dominion over the inhabitants as well of the water as of the air and earth; with his hand he constructs the lyre and lute, and the numerous instruments employed in the several arts of life; with the hand he erects altars and shrines to the immortal gods; and, lastly, by means of the same instrument he bequeaths to posterity, in writing, the intellectual treasures of his own divine imagination; and hence we, who are living at this day, are enabled to hold converse with Plato and Aristotle, and all the venerable sages of antiquity."

In reasoning on the utility of the hand, as characteristic of the human species, Galen thus expresses himself:* "Man being naturally destitute of corporeal weapons, as also of any instinctive art, has re-

* Lib. I. cap. 4.

ceived a compensation, first in the gift of that peculiar instrument the hand; secondly in the gift of reason; by the employment of which two gifts he arms and protects his body in every mode, and adorns his mind with the knowledge of every art. For since, had he been furnished with any natural weapon, he would have possessed the use of this alone on all occasions; or had he been gifted with any instinctive art, he would never have attained to the exercise of other arts; hence he was created destitute of those insulated and individual means and arts, which characterise other animals; inasmuch as it is manifestly preferable to have the power of making use of various means and various arts. Rightly, therefore, has Aristotle defined the hand to be the instrument antecedent to, or productive of, all other instruments: and rightly might we, in imitation of Aristotle, define reason, as opposed to instinct, to be the art antecedent to, or productive of, all other arts. For as the hand, though itself no particular organ, is yet capable of being adapted to all other organs, and is consequently antecedent to them; so reason, though itself no particular art, is yet capable of comprehending and applying all; and may therefore be considered as an art antecedent to all others. Thus man alone, of all animals, possessing in his soul this general and original capacity, is justly endued in his body with this general and original instrument."

" *Let us then scrutinize this member of our body; and inquire, not simply whether it be in itself useful for all the purposes of life, and adapted to an animal endued with the highest intelligence; but whether its entire structure be not such, that it could not be improved by any conceivable alteration.

"In the first place, it possesses in an eminent degree a leading quality of an organ of grasp; since it readily applies itself to, and securely holds, bodies of every form and size that are capable of being moved by human strength. Nor need we inquire whether it be better for this purpose that it should be divided into several parts; or, that it should be altogether undivided: for is it not apparent without further reasoning, that had it been undivided, it could have grasped only just such a portion of every object presented to it, as was equal to itself; but that, being divided into many parts, it can both easily grasp bodies much larger than itself; and can accurately search out, and lay hold of, the smallest particles of matter. For to the former it is capable of generally applying itself so, as to encompass them by the separation of the fingers; while in laying hold of very minute objects, the entire hand is not employed, but only the tips of two of the fingers: because from the grasp of the whole hand minute objects would easily escape.

"Thus then the hand is framed in the manner most convenient for laying a firm hold on objects both greater and less than itself. And in order to enable it to apply itself to objects of various shapes, it is

* Lib. i. cap. 5.

evidently most convenient that it should be divided into many parts, as it is: and it seems to be better constituted for this purpose than any similar instrument; for it not only can apply itself to substances of a spherical form, so as to touch them with every part of itself; but it also can securely hold substances of a plane or of a concave surface; and, consequently, it can hold substances of any form.

"And, because many bodies are of too great a size to be held by one hand alone, nature has therefore made each hand an assistant to its fellow; so that the two, when together laying hold of bodies of unusual bulk, on opposite sides, are fully equivalent to a single hand of the very largest dimensions: and, on this account, the hands are inclined towards, and in every point are made equal to, each other; which is at least desirable, if not necessary, in instruments intended to have a combined action.

"Take then any one of those unwieldly bodies, which a man can only lay hold of by means of both his hands, as a millstone or a rafter; or take one of the smallest objects, as a millet-seed or a hair, or a minute thorn; or, lastly, reflect on that vast multitude of objects of every possible size, intermediate to the greatest and the least of those above-mentioned; and you will find the hands so exactly capable of grasping each particular one, as if they had been expressly made for grasping that alone. Thus the smallest things of all we take up with the tips of the fingers; those which are a little larger we take up with the same fingers, but not with the tips of them; substances still larger we take up with three fingers, and so on with four, or with all five fingers, or even with the whole hand: all which we could not do, were not the hand divided, and divided precisely as it is. For suppose the thumb were not placed as it is, in opposition to the other four fingers, but that all the five were ranged in the same line; is it not evident that in this case their number would be useless? For in order to have a firm hold of anything, it is necessary either to grasp it all round, or at least to grasp it in two opposite points; neither of which would have been possible, if all the five fingers had been placed in the same plane: but the end is now fully attainable, simply in consequence of the position of the thumb; which is so placed, and has exactly such a degree of motion, as, by a slight inclination, to be easily made to co-operate with any one of the four fingers. And no one can doubt that nature purposely gave to the hands a form adapted to that mode of action, which they are observed to have;* while in the feet, where extent of surface is wanted for support, all the toes are arranged in the same plane. †But, to return to a point which we were just now considering, it is not merely necessary in laying hold of minute objects to employ the extremities of the fingers opposed to each other, but that those extremeties should be exactly of the character they are, namely soft, and round, and furnished with

* Lib. ii cap. 9.

† Lib. i. cap. 6.

nails: for if the tips of the fingers were of bone, and not of flesh, we could not then lay hold of such minute bodies as thorns or hairs; or if they were of a softer and moister substance than flesh, neither then could such small bodies have been secured. For, in order that a body may be firmly held, it is necessary that it be in some degree infolded in the substance holding it; which condition could not have been fulfilled by a hard or bony material; and on the other hand, a material too soft would easily yield to substances of which it attempted to lay hold, and would continually let them escape: whereas the extremities of the fingers are just of that intermediate degree of consistence, which is calculated for their intended use.

"* But, since tangible substances vary much in their degree of hardness, nature has adapted the structure of the extremities of the fingers to that circumstance: for they are not formed either entirely of flesh, or of the substance called nail; but of a most convenient combination of the two: thus those parts which are capable of being mutually brought in apposition, and which are employed in feeling for minute objects, are fleshy; while the nails are placed externally, as a support to the former. For the fingers are capable of holding soft substances, simply by the fleshy or soft part of their extremity; but they could not hold hard substances without the assistance of nails; deprived of the support of which the flesh would be forced out of its position. And on the other hand, we could not lay hold of hard substances by means of the nails alone; for these being themselves hard, would easily slip from the contact of hard bodies.

"Thus then the soft flesh at the tips of the fingers compensating for the unyielding nature of the nails, and the nails giving support to the yielding softness of the flesh, the fingers are hereby rendered capable of holding substances that are both small and hard. And this will be more evident, if you consider the effect of an unusual length of the nails; for where the nails are immoderately long, and consequently come in contact with each other, they cannot lay hold of any minute object, as a small thorn or a hair: while on the other hand, if, from being unusually short, they do not reach to the extremities of the fingers, minute bodies are incapable of being held through defect of the requisite support: but if they reach exactly to the extremities of the fingers, they then, and then only, fulfil the intention for which they were made. The nails, however, are applicable to many other purposes besides those which have been mentioned; as in polishing and scraping, and in tearing and pealing off the skin of vegetables, or animals: and in short, in almost every art where nicety of execution is required, the nails are called into action."

In alluding to the sceptics of his time, the language of Galen is as follows. †"Whoever admires not the skill and contrivance of

* Lib. i. cap. 7.

† Lib. iii. cap. 10.

nature, must either be deficient in intellect, or must have some private motive, which withholds him from expressing his admiration. He must be deficient in intellect, if he do not perceive that the human hand possesses all those qualification swhich it is desirable it should possess; or if he think that it might have had a form and construction preferable to that which it has: or he must be prejudiced, by having imbibed some wretched opinions, consistently with which he could not allow that contrivance is observable in the works of nature."*

Galen then sums up this part of the argument. "The contrivances of nature are so various, and so consummately skilful, that the wisest of mankind, in endeavouring to search them out, have not yet been able to discover them all."† And nearly in the same words, expressive of the same sentiment, does Solomon say—"Then I beheld all the work of God, that a man cannot find out the work that is done under the sun: because though a man labour to seek it out, yet he shall not find it; yea farther; though a wise man think to know it, yet shall he not be able to find it."‡

I may be permitted, perhaps, to subjoin a passage from another part of the same work of Galen, though not confined to the same subject; in which, after having noticed many evidences of design in the construction of the human body, particularly the adaptation, in the number and size of the parts, to the effect to be produced, he breaks out into this remarkable apostrophe: ‖ "How can a man of any intelligence refer all this to chance, as its cause: or, if he deny this to be the effect of foresight and skill, I would ask, what is there that foresight and skill do effect? For surely where chance or fortune act, we see not this correspondence and regularity of parts. I am not very solicitous about terms; but if you choose to call that chance which has so nicely constructed and so justly distributed all the parts of an animal body, do so; only remember and allow, that in so doing you do not fairly exercise the privilege of framing new terms: for in this way you may call the meridian splendour of the sun by the name of night; and the sun itself, darkness. What! was it chance that made the skin give way so as to produce a mouth? or, if this happened by chance, did chance also place teeth and a tongue within that mouth? For, if so, why should there not be teeth and a

* Galen adds: "Such persons we are bound to pity, as being originally infatuated with respect to so main a point; while at the same time, it behoves us to proceed in the instruction of those happier individuals, who are not only possessed of a sound intellect, but of a love of truth."

On another occasion, in reprobating such cavillers, he says: (lib. iii. cap. 10.) "But if I waste more time on such profligates, virtuous men might justly accuse me of polluting this sacred argument, which I have composed as a sincere hymn to the praise and honour of the Creator; being persuaded that true piety to him consists, not in the sacrifice of whole hecatombs of oxen, nor in the offer of a thousand varieties of incense; but in believing within ourselves, and in declaring to others, how great he is in wisdom, power, and goodness."

† Lib. x. cap. 10. ‡ Eccles. viii. 17. ‖ Lib. xi. cap. 7. and 8.

tongue in the nostrils, or in the ear?" Or, to carry on a similar appeal, "did chance dispose the teeth themselves in their present order; which if it were any other than it is, what would be the consequence? If, for instance, the incisors and canine teeth had occupied the back part of the mouth, and the molar or grinding teeth had occupied the front, what use could we have made of either? Shall we then admire the skill of him who disposes a chorus of thirty-two men in just order; and can we deny the skill of the Creator, in disposing the same number of teeth in an order so convenient, so necessary even for our existence?"

He then extends the argument to the teeth of other animals, as corresponding with the nature of their food; and also to the form of their feet, as having a relation to the character of their teeth.

"Never," says Cuvier, one of the most experienced physiologists of the present age, "never do you see in nature the cloven hoof of the ox joined with the pointed fang of the lion; nor the sharp talons of the eagle accompanying the flattened beak of the swan."

In corresponding expressions Galen exclaims, "* How does it happen that the teeth and talons of the leopard and lion should be similar; as also the teeth and hoofs of the sheep and goat; that in animals which are by nature courageous, there should be found sharp and strong weapons, which are never found in those animals that are by nature timid: or, lastly, that in no animal do we meet with a combination of powerful talons with inoffensive teeth? How should this happen, but that they are all the work of a Creator, who ever kept in mind the use and mutual relation of different organs, and the final purpose of all his works?"

CHAPTER IV.

On the Brain, considered as the Organ of the Intellectual Faculties.

It can no more be doubted that many of the phenomena of nature, and the important practical and philosophical conclusions deduced from them, would have been hitherto concealed from human knowledge, had man failed to exercise those intellectual faculties with which the Creator has endued him; than that political communities would have failed to exist, and social life to be adorned with the arts of civilization, had all mankind determined to pursue the mode of life adopted by savage tribes: nor can it be doubted that the Creator, in imparting to man intellectual faculties superior to those of brutes, in-

* Lib. xi. cap. 8. ed. Kühn. vol. iii. p. 875 lin. 3—17. and p. 892. lin. 12.—17.

tended that he should exercise them, not solely with a view to the higher and future destination of his nature, but also with a view to the purposes of this present life.

Since however the senses of hearing, sight, and touch, which are the great inlets of knowledge, are possessed by many of the inferior classes of animals in common with ourselves, by some indeed in a more exquisite degree; since also those animals are capable of remembering past, and conjecturing future events, although incapable of the more abstract functions of the understanding; it becomes highly interesting to inquire whether there is anything in the physical structure of man which renders him more capable of being acted on by external agents, with respect to the developement of his intellectual faculties, than brutes are: in other words, whether there is a material instrument in animal organization, the general composition of which is in obvious correspondence with the degree of intellect evinced by different species of animals, including man as one of those species.

Now, if any one in the least degree conversant with the laws of optics and of sound, were to doubt the adaptation of the structure of the eye and of the ear to those laws respectively, he would fairly be ranked among the individuals of that class of speculatists whose minds are too weak to apprehend any truth. And though there is not so obvious a relation between the structure of the brain and the exercise of the mental faculties, as in the case of the eye and light, and of the ear and sound; yet the indications of a mutual connexion between the two are both clear and numerous. And hence not only have philosophical inquirers in all ages acknowledged such a connexion; but the most common observers have ever felt an intuitive conviction of its existence, and have considered the brain as the instrument of thought and reason:* the truth of which assertion is evident from various metaphorical terms expressive both of intellectual defect and of intellectual excellence.

It may be presumed that, without the aid afforded by the study of anatomy or natural history, the most cursory observer might discover that the indications of intelligence manifested by the various classes of animals generally correspond in degree with their approximation in physical structure to man; and that, if we confine our view to the four highest classes, namely fish, reptiles, birds, and quadrupeds, and consider them with reference to their respective degree of docility; fish and reptiles, which are the lowest in the scale, will readily be allowed to be inferior to birds, which are a degree

* . . . . and his pure brain
Which some suppose the soul's frail dwelling house
Doth, by the idle comments which it makes,
Foretell the ending of mortality.
King John, Act 5, Scene 7.

higher in the scale; and these again will with equal readiness be allowed to be inferior to quadrupeds, which are the highest.

And it would be acknowledged upon a more accurate investigation, that, although there are at first sight some seeming exceptions to the regularity of gradation, the apparent anomalies vanish when put to the test of a philosophical examination. Should it be said, for instance, that the bee or the ant shows greater indications of intelligence than many species much higher in the scale of animal creation, it may be answered that those indications are manifested in actions which are referable to instinct, rather than intelligence; actions namely, which being essential to the existence of the individuals, and the preservation of the species, are apparently determined by some internal impulse which animals unconsciously obey. Nor does it militate against such a notion of instinct, that when accidental impediments prevent the regular evolution of the comb, taking that as an instance, the bee accommodates the arrangement of its fabric to the impediment which is placed in its way: for such a modification of instinct is as clearly necessary in the case of an occasional impediment, as instinct itself is necessary for the general purpose.

In speaking of instinct I purposely avoid a formal definition of the term: for any attempt to define with accuracy a principle, of the real nature of which we are ignorant, usually leaves us in a state of greater darkness than we were before; of which the following extraordinary attempt, with reference to the very principle now under consideration, is a sufficient illustration. It is quoted from an author of the name of Wagner, in a work on the Brain of Man and other Animals, written by Wenzel and his brother; and is as follows: "The instincts of animals are nothing more than inert or passive attractions derived from the power of sensation: and the instinctive operations of animals nothing more than crystallizations produced through the agency of that power."*

Of the general position, then, that the brain is the instrument of intelligence, and that the degree of intelligence characteristic of different classes of animals is proportional to the approximation of their structure to that of man, it may for the present be presumed that no one doubts.

* "Instinctus animalium nihil aliud sunt, quam attractiones mortuæ a sensibilitate profectæ; et eorum artificia nihil aliud quam crystallizationes per sensibilitatem productæ." Wenzel, De penitiori Structura Cerebri. Tubingæ, fol. 1812. p. 248, l. 10.

CHAPTER V.

THE NERVOUS SYSTEM OF ANIMALS IN GENERAL.

Section. I.

The Nervous System of the inferior Animals.

As the peculiarities in the structure of the human brain cannot be understood without a reference not only to the brain but to the nervous system at large of other animals; it will be necessary to take such a survey of that system as may be sufficient for the present purpose.

In the lowest species of animals, which appear to be devoid of any specific organs of digestion, motion, or sensation; whose economy indeed only enables them to contribute, in a mode as yet unknown, to the nutrition and preservation of the individual, or to the continuation of the species, no distinct nervous system has yet been discovered, or at least satisfactorily demonstrated: it is presumed rather than known that in such animals there exists a variable number of small insulated masses of nervous matter called *ganglions*, which are connected with each other, and with different parts of the body, by means of slender filaments that radiate from these masses in various directions.

In ascending the scale of animal existence we meet with species, in which, though devoid of organs of sense and motion, there exist distinct organs of digestion: and in such species the upper part of the passage leading from the mouth to the stomach is usually surrounded by a kind of collar, from whence distinct nerves are distributed to the other parts of the body.

In ascending still higher the scale of animal existence we find, together with a greater symmetry of structure in the whole individual, additional component parts of the nervous system, and a greater degree of regularity in the distribution of these supperadded parts. Thus in those classes of animals which include the leech, the centipede, and the bee, whose bodies are naturally divisible into distinct segments, we find a series of ganglions placed opposite the respective segments, and sending out nerves which are appropriated to the muscles of voluntary motion attached to these segments: and the several ganglions are reciprocally united by intervening portions of a nervous cord, which is continued from one extremity of the body to the other; so as to present the appearance of a thread in which knots have been tied at stated intervals. And in those species of these classes which have eyes, as is the case with

insects, there are additional ganglions near the head; from which arise the nerves of vision, and probably, of touch.

If, in ascending still higher the scale of animal existence, we examine the nervous system of fish, reptiles, birds, and quadrupeds, we find that those parts which are subservient to the nutrition of the individual, and to the continuation of the species, are supplied with ganglions and nerves corresponding in their general character and mode of distribution with the nervous system of the lower classes: and that the arrangement of the nerves of voluntary motion merely differs from that of the intermediate classes, in being more elaborate; the individual nerves all communicating with a continuous cord which extends from one extremity of the body to the other; but which instead of floating loosely in the general cavity of the body, as in insects, &c. is contained in a canal essentially consisting of a series of parts called *vertebræ*, which taken together form what is called the spine or backbone. From the structure of this spine these classes are called *vertebrated:* and it is deserving of notice that these classes alone have a *cranium*, or skull.

The nervous cord above described is known more familiarly under the name of the spinal *marrow*, a term which is derived from its resemblance, in some of its physical characters, to the oil contained in the interior of the bones of man and various other animals.

That portion of the spinal cord which is contiguous to the head is continued into the cavity of the skull; and is there apparently lost in a more or less regular mass of nervous matter called the brain: which is small, and simple in its structure, in fish; larger, and more complicated, progressively, in reptiles, birds, and quadrupeds; largest, and most complicated, in man. From the lower surface of the brain arise several pairs of nerves which are principally distributed upon the organs of the distinct senses, and muscles of the face; and it is worthy of observation, that while the muscles of mere animal motion, as of the trunk and extremities, are derived from the spinal marrow; the muscles of the face, which may be called pre-eminently the muscles of moral and intellectual expression, are derived from the brain itself.

In ascending then from fish, the lowest of the four classes of vertebral animals, to quadrupeds which constitute the highest class, the general mass, of the brain upon the whole increases in proportional size; and at the same time it also more and more resembles that of man both in its general form, and in the character and proportions of its several parts. But the human brain, when fully developed, contains parts which do not exist in the brain of those animal species which approach nearest to man in the structure of this part.*

* It may be convenient here to state that the human brain is naturally divisible into two parts, called the *cerebrum* and *cerebellum;* of which the former is eight or

It cannot be uninteresting in an inquiry like the present to add, with respect to those occasional deviations from the common form, called monsters and lusus naturæ, that nature never elevates the brain of an individual of a lower to that of a higher class; though the brain of an individual of a higher is frequently not developed beyond the degree of a lower: and this law of the developement of the brain is, with reference at least to the distinction of classes, correspondent with that of the general form. Thus a lusus naturæ or monster in the class of quadrupeds, for instance, or of birds, may have two heads, or eight legs; but the supernumerary parts will be always those of its own class, indeed of its own species; and therefore it is absurd to suppose that if there be no mixture of species in the same class, there should ever be a confusion of two distinct kingdoms of nature.

Horace, than whom no one better understood the principles of imaginative or artificial poetry, knew that abrupt combinations of heterogeneous subjects would certainly offend a correct taste, because unnatural: for taste, it may be affirmed, is, in one of its essential attributes, a feeling in harmony with natural combinations; whether the individual combination be that of sounds, or colours, or forms, or of intellectual images, or moral sentiments: and nature, which may be pre-eminently called the τέχνη ποιητικὴ, though she may occasionally surprise the mind by unusual combinations of organs natural to the species, never so couples together heterogeneous organs, as that the limbs of animals of one species should be united with those of another species; in short, as Horace himself expresses the conception,

.... Non ut
Serpentes avibus geminentur, tigribus agni.*

Section II.

The Nervous System of Man.

The nervous system of man, without any reference to that of other animals, naturally resolves itself into three sufficiently distinct divisions: of which one is appropriated to those parts, which characterise him as simply an organized being; another, to his powers of voluntary motion; the third, or the brain, to the organs of the

nine times larger than the latter. The cerebrum, which occupies nearly the whole of the cavity of the skull, consists of two parts, called *hemispheres:* and it should be particularly borne in mind that it is with reference to the great size of its hemispheres that the human brain exceeds that of all other animals.

* The subject of lusus naturæ, or monsters, will be resumed towards the conclusion of this treatise.

several senses, and, probably, to the manifestation of the intellectual powers and moral affections.

Of the two first of the foregoing divisions it is not necessary to speak more at large; because no doubt exists in the minds of physiologists as to the nature of their offices. But this is not the case with respect to the brain; which therefore demands a greater share of our attention.

Of all the parts of the nervous system taken collectively, the brain has been most generally considered as the organ of the mind: and it has long been a favourite speculation to endeavour to ascertain what part of this organ is subservient to the existence and exercise of those intellectual powers and moral feelings, which to a greater or less extent are possessed by many other animals as well as man. It is presumed at least that of the existence of intellectual powers or moral feelings in brutes no one can doubt, who has been at all accustomed to observe the characters and habits of animals;* so that when in common language it is asserted that man differs from other animals in possessing reason, while they are irrational, the term reason must be taken in its most extended sense, as implying the aggregate faculties of man, both moral and intellectual.

I will not here insist on the evidence of the intellectual powers of brutes, as deducible from the effects of what we call instinct; because in all those actions which are the result of instinct, animals appear to be guided by a natural and irresistible impulse from within, which leads them to seek or to avoid that which will be either useful or injurious to them; and enables them to perform the most complicated acts, as the building of a nest or the construction of a comb, though they may never even have seen the same acts performed by other individuals of their species. I would rather insist on that evidence of their intellectual powers, which is derived from their conduct, when, in consequence of having been removed from their natural sphere of action, they are impelled by external and accidental circumstances. Thus the wariness of old animals in avoiding the pursuit or arts of man, and the sagacity with which a practised hound will cut off an angle in order to shorten his distance, may be considered as proofs of a considerable degree of intellectual rather than of instinctive prudence in brutes.

The playfulness of the young of most quadrupeds, often indeed observable in the adult animal also, may be regarded as no obscure proof of the exercise of the intellectual faculty which we call imagination; for that playfulness almost always consists in the representation of mutual hostility, though the real disposition at the same time is anything but hostile. The dog for instance, under such

* Aristotle, in his History of Animals, distinctly affirms such an existence—ἔνεστι γὰρ ἐν τοῖς πλείστοις καὶ τῶν ἄλλων ζῴων ἴχνη τῶν περὶ τὴν ψυχὴν τρόπων, ἅπερ ἐπὶ τῶν ἀνθρώπων ἔχει φανερωτέρας τὰς διαφοράς. p. 212. lin. 7—10. ed. Bekker.

circumstances, snarls and bites, but with evident intention not to hurt.

Of the existence of moral feelings in brutes, there is still more decided proof than of the existence of intellect. Thus the expression of joy in a dog at sight of his master is not to be mistaken, and the expression of fear in a horse at the sound of the whip is equally unequivocal in its character. Again, animals become attached not only to individuals of their own species, but to individuals of even a different order or class: and they evidently feel regret upon separation from these their companions.

On the supposition that the brain is the organ of the intellectual powers, physiologists have been led to compare the proportions of the whole and of its several regions in man and brutes; in order to arrive at a knowledge of such facts as might serve for a basis for ascertaining which are the parts essential to its action as such an organ. It has been supposed by some that the intellectual faculties may be in proportion to the *absolute* size of the brain; such an opinion being grounded on the fact, that the human brain is larger than that of the horse or ox. But on the other hand, the brain of the whale or of the elephant taken in its whole mass is larger than that of man; though the intelligence even of the elephant bears no proportion to that of the human mind. Again, the brain of the monkey or of the dog is smaller than that of the ox or the ass; yet with respect to their intellectual faculties the former approximate much more closely to man than the latter. Neither do the dispositions or qualities of animals appear to be connected with the absolute size of their brain: for animals most different and even opposite in disposition may be ranged in the same class with reference to the size of this organ; the tiger and the deer, for instance, among quadrupeds; and among birds, the hawk and the pigeon.

It would appear probable from some instances, that the *proportional* size of the brain with reference to the size of the body would give a more uniform result. Thus a crocodile twelve feet in length, a serpent eighteen feet in length, and a turtle that weighs from three hundred to five hundred pounds, have not any of them a quantity of substance in their brain equal to half an ounce; and the slight degree of intellectual power manifested by these animals corresponds with such a proportion. But on examination it appears that the proportional size of the brain is not a more certain criterion than the absolute size. The brain of the elephant for instance is smaller in proportion to its body than that of any other quadruped: and yet what quadruped exceeds the elephant in sagacity? and, in comparing many of the inferior animals with man in this respect, it is found that not only do different genera of the same order differ very widely from each other in the proportion of their brain to their body, as the bat and the fox; but that the proportion is sometimes inversely as the degree of intellect of the animal: thus, as far as we

are capable of judging, the intellect of the fox is infinitely greater than that of the bat, and yet the brain of the former, proportionally to its body, is only one half the size of the latter. Occasionally the disproportion is still greater in different species of the same genus, and even in different varieties of the same species: thus in some dogs the brain compared with the body is as one to fifty, while in others it is as one to three hundred.

Again, it appears that the brain of some of the genera of the lowest orders in a class is proportionally larger than that of some of the genera of the higest orders. Thus, in the mammalia, the brain of the dolphin, which animal is in the lowest order of that class, is in proportion to its body four times as large as the brain of the fox, which is an animal of one of the highest orders. And the brain of the mouse and of the mole are nearly, if not quite as large, in proportion to their body, as that of man. And the same circumstance occurs even in the second class, or birds; for the brain of the sparrow is in proportion to the body, as large as, nay even larger, than that of man.

Lastly, for it is unnecessary, and would be tedious, to enter further into the detail of this part of the subject, there does not appear to be any connexion between the degree of intellectual faculties and the mutual proportions of the several constituent parts of the brain; or between the degree of intellectual faculties and the mutual proportions of the brain and nerves. So that it appears, from a review of what has been advanced, that no criterion of the degree of intellect is found in the absolute size of the brain; nor in its relative size, as compared with that of the body of the individual; nor in the relative size of its constituent parts, or of the whole of it, to the nerves.

Section III.

Indications of natural Talent and Disposition deducible from the Structure of the Brain.

If the entire history of the brain were a primary object in this treatise, it would be right here to investigate in detail the observations and theory of Dr. Gall respecting this organ: but on the present occasion it will be unnecessary to refer to that theory further than may be required by the course of the argument.

The simple enunciation of Dr. Gall's theory is this, that "the brain in general is the instrument by which the intellectual faculties, and the moral sentiments and propensities, are manifested; particular parts of it being the organs of those several faculties, sentiments, and propensities: and that according to the state of these organs

will be the faculties, sentiments, and propensities of each individual."

To those who have objected to this theory, that it leads towards the doctrines of fatalism, and the material nature of the soul, it has been answered; first, that as, according to the theory, no individual, who is endued with intellect, is deficient in the organs of those moral sentiments, which, if cultivated, will be sufficient to counteract whatever bad propensities he may have, the theory cannot consistently be accused of inculcating the doctrine of fatalism: and secondly, that without inquiring what the soul is, or in what manner it is united to the body in this life, which Dr. Gall considers as questions not only beyond the comprehension of human reason, but totally unconnected with his inquiries, the theory merely investigates the *material* conditions of that part of the body by which the soul is affirmed to manifest itself to our observation.

It has been already stated that, in exposing to view the lower surface of the brain, several pairs of nerves are observable which may be traced to the organs of sense and some other parts: and it is admitted by many anatomists of acknowledged accuracy, that, of all these pairs, not one, excepting the olfactory and optic, is derived from the great mass of the brain called its hemispheres: but Dr. Gall shows it to be highly probable in fact, as it evidently is in reasoning, that neither the olfactory nor the optic nerves are derived from the hemispheres: whence it would appear that, with the doubtful exception of the nerves of smell and sight, not a single nerve of the whole body is derived from the great mass of the brain: for the organs of the other senses, and all the muscles of voluntary motion, together with the whole assemblage of the organs of digestion, and the heart, and the lungs, are evidently supplied from other sources.

Either then the great mass of the brain is allotted in a most anomalous disproportion to the two senses of smell and sight, which in many animals are comparatively weak; or, if it do not supply the nerves of sight and smell, there is no part of the body which it does apparently supply with nerves: and then the conclusion presses upon us with peculiar force, that the brain is exclusively the instrument of the immaterial part of our present existence.

It appears from Dr. Gall's own account, that he was originally led to this peculiar train of thought by observing the difference of talents and character in his own brothers, and in other children with whom he happened to associate; some of whom, though under perfectly similar circumstances of education with the rest, were much quicker in apprehending what was taught them: and further, by observing in different individuals of the same species of animals, as dogs, that some were fierce, some mild: again, that in birds of the same species some continued to sing their own notes only, while others would listen to, and imitate, artificial music: and with reference to

the last-mentioned instance particularly, he argued that the difference could not arise from the greater or less degree of perfection in the organ of hearing, for it is the same in both; but must be looked for in the brain, to which the organ of hearing conveys sounds; and in which, and not in the ear itself, they are perceived. There are moreover numerous instances which show that the sense of hearing is by no means in proportion to the degree of perfection in the construction of the ear. Thus, the dog, hears with indifference the sweetest melody: and yet the construction of his ear approximates more to that of man than the construction of the ear of even the most musical birds. And on this point Dr. Gall asks, if the organ of hearing determine the power of singing, why should the female bird be mute, seeing that in this part of its bodily construction it differs not from the male? It is equally observable that in men the talent for music is not in proportion to any superiority in the organ of hearing; in the construction of which indeed there is little if any apparent difference between any two individuals.

Partial insanity and partial idiotcy are among the circumstances which Dr. Gall considers as favouring his theory. The frequency of the former must be a fact well known to all: the latter is not uncommon; and even persons of considerable intelligence occasionally exhibit very obscure traces of this or that particular faculty. Other arguments in favour of his system he draws from the temporary effects produced by cerebral inflammation on the state of the mental powers: in the case, for instance, of idiots, who during the inflammatory action have manifested a considerable degree of understanding; but after the cessation of that action have relapsed into their former state of fatuity.

It would seem, in the instances here adduced by Dr. Gall, that the mental faculties which had been previously in a state of fatuity, are rendered for the time rational, in consequence of a degree of excitement which in individuals not labouring under fatuity would have probably produced delirium: and, as a rational state of the faculties may be considered, to use a mathematical expression, as a mean proportional to fatuity and delirium, it might be expected that the same cause which would raise a rational state of the faculties to delirium, would raise an idiotic only to a natural state: as, in a similar manner, wine is observed to modify the characters of individuals of different temperaments, by elevating them for the moment:

> "It keeps the unhappy from sinking,
> And makes e'en the valiant more brave."

It would occupy too much time to enter into the detail of this interesting part of Dr. Gall's system: nor was more originally intended than to introduce the subject to the consideration of those, who happen not to have reflected on it before, in such a manner as to enable them to form some judgment of the merits of a theory, the charac-

ter of which has been injured to the full as much by its injudicious friends as by its professed enemies. Of this theory it may perhaps be affirmed with truth, that, considered as an abstract philosophical speculation, it is highly ingenious, and founded upon unobjectionable principles: and that while the general conclusion is inevitable with respect to the collective functions of the brain, there is nothing unreasonable in supposing that specific parts serve specific purposes. The rock, on which Dr. Gall and his implicit advocates have split, is the attempt to fix the local boundaries of the several faculties of the soul. Had he satisfied himself with developing the structure of the brain in the various classes of animals; and had he been content to show that, in tracing its structure from those animals which manifest the least indications of intelligence to those which exhibit still stronger and stronger, it proportionally advances in its resemblance to the structure of the human; and lastly, had he only drawn from these premises the general probable conclusion, that specific parts had specific uses with respect to the manifestations of the immaterial principle of animal existence: (and assuredly brutes are endued with such a principle, though, as being devoid of the moral sense, they are not fitted for a future state, and consequently perish when their bodies die;) had Dr. Gall been content to have stopped at this point, without venturing to define the local habitations of the supposed specific organs, he would have acquired the unalloyed fame of having developed a beautiful train of inductive reasoning in one of the most interesting provinces of speculative philosophy: whereas, in the extent to which he has carried his principles, his doctrine has become ridiculous as a system; while in its individual applications it is not only useless, but of a positively mischievous tendency: for, without the aid of this system, every man of common sense has sufficient grounds on which to judge of the characters of those with whom he associates; and it is evidently more safe to judge of others by their words and actions, and the general tenor of their conduct, than to run the risk of condemning an individual from the indication of some organ, the activity of which, for a moment allowing its existence, may have been subdued by the operation of moral or religious motives.

But there is an occasional absurdity in the application of the theory, which, though obvious, does not seem to have been noticed. Let us suppose, for instance, the case of a *murderer;* and that a disciple of Dr. Gall were to maintain that, as the crime of murder proceeds from the operation of the organ of destructiveness, that organ would be found highly developed in such an individual; and yet, upon actual inspection, this were not found to be the case. Here, although the disciple of Dr. Gall might be disappointed in finding no such developement, a plain reasoner would not be so disappointed: for is it not obvious that *avarice*, or *shame*, or *jealousy* might in a moment operate so powerfully as to lead an individual to the crime

of murder, whose nature and habits were as far as possible removed from the propensity to that crime; and who, consequently, according to Dr. Gall's own principles, would be devoid of any undue developement of the organ of murder?

With respect to ourselves indeed, the study of the system may be attended sometimes with the happiest consequences: for if, from the contemplation of it, we can be strengthened in our conviction of the fact, which both reason and revelation teach us, that each individual is liable to particular temptations depending on his specific temperament, we shall thus have one additional memento of our frailty, one additional incentive to watch over, and combat, "the sin which doth so easily beset us."

Section IV.

The general Doctrine of Physiognomy, as connected with the Form of the Body.

As the indiscreet zeal, not only of Dr. Gall, but of physiognomists in general, has thrown unmerited discredit on that department of speculative philosophy which they have cultivated, it may be worth while to examine the subject on other authority than that of professed physiognomists.

There are many phenomena, then, connected with the moral and intellectual faculties of man, both in a healthy and diseased state, which, by showing the reciprocal influence of the two distinct parts of our nature, the soul and the body, render it probable that the energies of the former, although it be itself immaterial, may be manifested by means of a material instrument. The existence of this reciprocal influence, which indeed we might expect from their intimate though mysterious union, cannot be denied. Thus grief or expectation destroys appetite; and mental application to any favourite pursuit makes us insensible of the want of food: and, on the other hand, a disordered state of the digestive organs evidently impedes the free exercise of the mental powers; or oppresses the soul with those dreadful, though really groundless apprehensions, which have been termed *hypochondriacal* from the situation of the organs, the morbid state of which is supposed to give rise to those apprehensions. Again, intoxication confuses the memory and judgment; and the repeated abuse of wine permanently debilitates the mind, and often terminates in confirmed insanity. The state of the air affects the mental energies and moral feelings of many individuals, to a degree inconceivable to those who are not thus subject to its influence. And the impression of fear has been known suddenly to arrest the symptoms of endemic ague and epilepsy.

The general idea that this connexion of the soul and body may be

traced in the conformation of the latter, it will be at once remembered, is by no means new: and the anecdote of the unfavourable judgment passed on the moral disposition of Socrates, from the character of his countenance, will readily recur to the mind on this occasion. Aristotle has even entered into some details on the forms and shades of colour of the hair and features, and indeed of various other parts of the body, as indicative of particular temperaments or constitutions of the mind.* And it is hardly a question, whether every individual is not accustomed in some degree to decide on character from the features, the colour of the hair, and other external indications, indedendently of that expression of the countenance, which rather marks the actually existing state of the mind than the latent disposition of it.† But if it be in any degree probable that the connexion between the soul and body may be traced in the conformation of the features or other parts of the body, in a much greater must it be probable that that connexion may be traced in the structure of the brain.

Nor does there appear, on the ground either of reason or of religion, any thing objectionable or absurd in the assumption, antecedently to observation, that the intellectual and moral tendencies of the soul may in a qualified sense be determined, or at least modified, by the peculiar structure of the body: that they are frequently coincident with certain peculiarities of corporeal structure is a matter of actual observation.

Is it absurd to suppose that, man being a compound of soul and body, the body has been so constructed in each individual as to become a fit arena on which that struggle shall be manifested, which undoubtedly takes place between the conflicting passions of the soul? For it will not be denied by those to whom this treatise is addressed, that the soul wants not the substance of a corporeal frame for the mere existence of its evil principles, but only for the external mani-

* For an exposition of Aristotle's views on this subject, consult a work of Galen, entitled ΠΕΡΙ ΤΩΝ ΤΗΣ ΨΥΧΗΣ ΗΘΩΝ, in which the question of the connexion between the faculties of the soul and the conformation of the body is discussed. Galen. op. Kühn. vol. iv. p. 768—798.

† Shakspeare has several references to indications of personal character, as depending on the form of the countenance, &c.

Cleopat. Bear'st thou her face in mind? i'st long, or round?
Messeng. *Round,* even to *faultiness,*
Cleopat. For the most part too,
They are *foolish* that are *so.* Her hair, what colour?
Messeng. Brown, madam: and her *forehead*
As *low* as she would wish it.

ANTONY AND CLEOPATRA, Act III. Scene 3.

Caliban. . . . . We shall lose our time,
And all be turn'd to barnacles, or to *apes*
With *foreheads villanous low.*

TEMPEST, Act IV. near the end.

Julia. Ay, but *her forehead's low; and mine's as high.*

TWO GENTLEMEN OF VERONA, end of Act IV.

festation of them. An authority at least which cannot be questioned by a believer in revelation, asserts that out of the heart, that is, evidently from the context, out of the soul, proceed murder, theft, adultery, and the like.

Is it absurd to suppose that, the brain being a very complicated organ, made up of distinctly different parts, these parts are subservient to the exercise of different functions? or, since it is evident that in every other individual organ of the body, where there is an identity of structure, there is also an identity of function in all the parts, may we not fairly presume that, were the integral parts different, the effects produced would be different; and, consequently, that as the integral parts of the brain differ from each other, the offices of those parts may be different? Or, again, will it be denied as a matter of fact that different faculties and propensities manifest themselves in different individuals; and is it unreasonable, on the ground of analogy, our only ground in this case, to suppose that they manifest themselves through the agency of different instruments? And since the visceral nerves are appropriated to the mere vital functions of nutrition; and the spinal nerves to general muscular motion and common sensation; and the nerves of the special senses occupy but a very small portion of the brain; to what assignable purpose can the great mass of that organ be applied, if not to the operations of that intellectual and moral principle, which, after the abstraction of the organs of nutrition, motion, and sensation, is the only imaginable part of our present nature?

Is the language of Scripture entirely allegorical throughout the sacred volume? or do we believe on just grounds that we are contaminated with an innate propensity to evil; that there are two principles within us constantly struggling for the mastery; and that, spite of our better part, and against the strongest feelings of conscience and determination of judgment, we still are for ever yielding to the worse?

Shall we deny that the tendencies to evil are different in character in different individuals; and by that denial shall we attempt to falsify the testimony of experience as to the fact itself; and the conclusions of antecedent reasoning as to its probability: for, if all men were avaricious for instance, or ambitious in the same points, where would be the field for the display of other qualities; and how could the affairs of the world be conducted?

But whatever may be the real state of the case—whether the brain act as a simple organ by the simultaneous operation of all its parts; or whether those parts act independently in the production of specific effects—no one can doubt that the organ itself is the mysterious instrument by means of which, principally, if not exclusively, a communication is maintained between the external world and the soul. Nor can it be doubted, indeed it is a matter of fact which is constantly open to our observation, that the degree of approximation in

the structure of the brain of other animals to that of man bears a very obvious relation to the degree of intelligence manifested by the various classes of animals: so that, in just reasoning, it must on every consideration be admitted to be the instrument by which the various degrees of intelligence are manifested.

It is a matter also of observation, that the powers of the mind are capable, like those of the body, of being strengthened by exercise and cultivation: and, further, that not only do the mental faculties gradually manifest themselves from the moment of birth onwards; but that the physical developement of the brain advances proportionally up to a certain period. But on this point it will be desirable to make a few more particular remarks.

Section V.

The Developement of the Human Brain, compared with that of other Animals.

The brain of all vertebral animals, including even man, is nearly identical in structure in the early period of the embryo state of those animals. But at the period of birth there is a very remarkable difference between the degree of developement of the human brain, and of that of the inferior animals. In quadrupeds for instance, the brain, according to Wenzel, is fully developed at the moment of the birth of the individual; contains, that is, at that time, all the parts in as perfect a state as they are in the adult animal of the same species (Wenzel, p. 246): while, with respect to the human species, it is asserted by Wenzel, and his statement is confirmed by the observations of others, that although the brain makes continual and rapid advances to its ultimate magnitude and perfect state, from the period of conception to the seventh year after birth, yet all the parts have not attained their full size till the age of seven years (p. 254). And this difference is exactly what might be antecedently expected, from the comparatively greater degree of intelligence manifested by the young of other animals, of the higher orders at least, than by the human infant.

But it is very worthy of observation, that those parts of the human brain, which are formed subsequently to birth, are entirely wanting in all other animals, including even quadrupeds, which Wenzel has examined (p. 246): and that during the evolution of the parts peculiar to the human brain, the peculiar faculties of the human intellect are proportionally developed: and finally, that, till those parts are developed, those faculties are not clearly perceptible (Wenzel, p. 247). But at the age of seven years the human being essentially possesses, although not yet matured by exercise and education, all those intellectual faculties which are thenceforward observable: and at that

age the brain is perfect in all its parts. And, from the age of seven years to the age of eighty, the changes of the human brain with respect to size, either collectively or in its several parts, are so trifling as hardly to be worth notice (p. 247—266).

In comparing either individual actions or the complicated operations of man, with those of other animals, it is observable, that the actions and operations of the adult human being as much excel in design and method the actions and operations of all other adult animals, as those of the infant are excelled in precision and adroitness by the young of all other animals (p. 247): and both these facts correspond with the relative constitution of the brain at the respective periods; the brain of other animals being perfect at birth, which is not the case with the infant; while the brain of the adult human being manifests a higher degree of organization than that of any other animal, and is therefore physically fitted for functions of a higher order.

It appears then highly probable, both from the intuitive conviction of mankind at large, and from a comparative examination of the structure and developement of the brain in man and other animals, that the intellectual superiority of man, physically considered, depends on the peculiarities of the human brain: and with respect to the rest of his body, it is certain that the hand is the instrument which gives him that decidedly physical superiority which he possesses over all other animals. In all other respects there is no physiological difference, of any importance at least to the present argument, between man and the higher orders of animals: and the peculiarities of his physical condition, with reference to the form and general powers of his body, rest therefore on those two organs, the *hand* and the *brain*. And as the adaptation of the external world to the physical condition of man must have a special reference to those peculiarities in his structure which distinguish him essentially from other animals, it has therefore been thought important to dedicate a considerable portion of this treatise to the investigation of the characters of the two organs above-mentioned.

Section VI.

Cursory View of the Extent of Human Power over the Objects of the External World.

Having examined, as far as is necessary for the purpose of this treatise, the animal character of man, both with respect to the points in which he partakes of the nature of other species, and those in which he is elevated above them; let us proceed to consider the adaptation of the external world to the physical condition of that being to whom the Creator has given dominion over all his other

works; whom alone, of all the living tenants of the earth, he has endued with a mind capable of conceiving, and corporeal powers capable of executing those wonderful combinations, which make him lord of the world which he inhabits; which enable him to compel the properties of inert matter to bend to his behests; and to direct not only the energies of the inferior animals, but even those of his fellow creatures, to the purposes which he may have in view.

In contemplating, for instance, as in all the pride of its appointments it advances through the waves, the majestic movements of a man-of-war, let us trace its whole history, and thence admire the extent of human power over the material world. Look at the rude canoe of the New Zealander, or call to mind the nearly as rude coracle of our own forefathers, and compare those simple and puny products of an infant art with the complicated and gigantic triumph of naval architecture now before you; and no wonder if, observing the ease and precision of its movements, the unlettered savages of the islands of the Pacific conceived the stupendous machine to be some form of animated matter; whose fierce nature and awful power were announced by the tremendous roar and destructive effects of artillery.

Or, passing from inert matter to living and intellectual agents, let us in imagination first view the tumultuary and predatory incursions of the aboriginal borderers of the Ohio, or even of the more civilized tribes of modern Arabia; revenge or booty their sole objects, without any plan of civil government or national aggrandizement; and then let us contemplate the profound views and combinations of the Macedonian monarch—that military meteor, whose course, though occasionally eccentric, was yet constantly regulated by the preponderating attraction of his original design; and whose plans, though marked by temporary and local devastation, yet secured the foundation of the durable and general prosperity of future generations. The theme is too vast and too sublime for the present effort, even had it never been before attempted; but the genius of the learned author of the "Commerce and Navigation of the Ancients"* has admirably developed the great and profound views of Alexander, ignorantly described by Pope as the reveries of insane ambition; and has significantly alluded to the successful accomplishment of his wonderful attempt, in that beautifully appropriate legend placed under the engraving of the head of his hero,

"Aperiam terras gentibus."†

Or let us investigate the career of the equally extraordinary conqueror of the present century. View him overcoming every moral and physical difficulty in the pursuit of his gigantic and fearful pro-

* The very reverend W. Vincent, D. D. late dean of Westminster.

† Q. Curt. lib. ix. cap. 6.

ject of universal empire; uniting distant and hostile nations in confederacies against their own liberties; changing their long established dynasties, in order to set over them kings of his own family. View him absorbed in his heartless calculations on the advantages to be obtained, for his personal aggrandizement, by the endless sacrifice of human life; breaking into the peaceful occupations of domestic scenes, and desolating the happiness of myriads of his subjects, not to ward off the dangers of hostile invasion, nor to lay the foundation of the future good of his country, but solely to gratify his own insatiable thirst of power; and yet by the magic of his name rallying round his standard, even to the last, the remnants of his former reckless schemes of inordinate ambition.

In meditating on the astonishing scene presented to the imagination by the description of a career so strange, we might almost be in doubt whether these effects were produced by a mere human mind; or marked the presence of a superhuman intelligence, permitted for a time to exercise a guilty world. But whatever he were, he is gone; and his place will know him no more. One moral reflection in the meantime forces itself upon the mind; partly applicable to himself, and partly to mankind at large.

Inebriated with prosperity, and regardless of the power which could alone uphold him, he fell from his towering height; and was banished far from the theatre of his former ambition, and almost, indeed, from the haunts of men. But, haply, the prolongation of his life in the silent retirement of that sequestered island was mercifully intended to lead him to a calm reflection on the real value of sublunary possessions: for how very visionary and like a dream must all his former life have frequently appeared to him, when standing on the brow of some precipitous rock, the natural boundary of his insulated prison, he mused on the interminable expanse of the Atlantic; and compared his present desolation with his former glory. Or, if the terrors of Omnipotence failed even then to reach his obdurate heart, his example at least remains a merciful beacon to others; who may learn from his doom, that there is a Power which can say, as easily to the tempestuous ocean of ambition, as to the deep, "Hitherto shalt thou come, but no further: and here shall thy proud waves be stayed."

CHAPTER VI.

ADAPTATION OF THE ATMOSPHERE TO THE WANTS OF MAN.

Section I.

The general Constitution of the Atmosphere.

In the foregoing part of this treatise the physical condition of man has been considered under the view of the capabilities of his nature, rather than of his actual state: but it is evident on a moment's reflection that his actual state will be very different at different periods of time, or in different parts of the world at the same period: and this observation applies no less to communities than to individuals. How great the contrast, with reference to the case of individuals, between the intellectual powers and attainments of a Newton and a native of New Holland; and in the case of communities, how great the contrast between any of the kingdoms of modern Europe, and the rude tribes from whence they were originally derived.

In proceeding then to illustrate the adaptation of the external world to the physical condition of the human species, we must view individuals or communities under all possible circumstances of existence, and make the illustration of as general application as the nature of the subject evidently demands.

And, in order to effect something like a systematic arrangement of the immense mass of materials whence the following illustration is to be deduced, it is proposed to investigate separately the four kingdoms or divisions of nature, the general characters of which were given in the commencement of this treatise; beginning with the atmospherical and ending with the animal kingdom.

If it were possible, with the bodily as with the mental eye, to behold the constitution of the atmosphere which surrounds our earth, we should view a compound probably the most complex in nature: for into this circumambient ocean of air, as it is called by Lucretius,* are carried up whatever exhalations arise not only from the earth itself, but from every organized form of matter whether living or in a state of decomposition that is found upon the earth's surface; the dews of morning, the balms of evening, the fragrance of every plant and flower; the breath and characteristic odour of every animal; the vapour invisibly arising from the surface of the whole ocean and its tributary streams; and, lastly, those circumscribed and baneful effluvia, however generated, which when confined to definite portions

* Semper enim quodcunque fluit de rebus; id omne
Aëris in magnum fertur mare. Lib. V. 277, 8.

of the atmosphere produce those various forms of fever which infest particular districts: or those more awful and mysterious miasmata, which, arising in some distant region, and advancing by a slow but certain march, carry terror and death to the inhabitants of another hemisphere.

Such is the complex character of the atmosphere; and, indeed, from this assemblage of vapours contained in it, it has received its peculiar appellation; being the receptacle, or magazine, as it were, of terrestrial exhalations.*

All these various exhalations however may be considered as foreign to the constitution of the air, being neither constantly nor necessarily present anywhere; all, with the exception of that aqueous vapour which is continually arising from the surface of the earth, as well as of the ocean and every lake and river. But, in addition to this aqueous vapour, the air is also charged to a variable extent with light and heat and electricity: of which the two first are so obvioulsy adapted to the wants of man as to demand immediate attention. Electricity is probably of equal importance in its relation to man: but the true character of that relation has not yet been sufficiently developed to call for a distinct consideration on the present occasion.

Section II.

Light.

The metaphorical expressions of all ages and nations, with respect to light, sufficiently evince the value in which that inestimable gift is held. In the sacred Scriptures indeed, not only are temporal blessings compared with light, and temporal evils to darkness; but holy deeds are frequently described under the character of the former; and unholy deeds under the character of the latter: and, with respect either to classical or oriental literature, a thousand instances might easily be adduced illustrative of the same metaphorical use of the terms in question.

When, after a dark and tempestuous night, the mariner first perceives the dawn of returning day; although that dawn discover to his view the evil plight to which the storm has reduced his vessel, why does he still hail day's harbinger as his greatest relief, but because without the aid of light he could not possibly extricate himself from the difficulties of his situation? Or, when the child, awakened from its sleep, finds itself alone in darkness, why is it overwhelmed with terror, and why does it call out for protection, but from the influence of those undefined fears, which naturally occur to the mind under the privation of light?

* Ἀτμων σφαῖρα.

There is something so congenial to our nature in light, something so repulsive in darkness, that, probably on this ground alone, the very aspect of inanimate things is instinctively either grateful or the reverse, in consequence of our being reminded by that aspect of the one or of the other: so that on this principle, perhaps, particular colours throughout every province of nature are more or less acceptable in proportion as they approach nearest or recede farthest from the character of light, whether reflected immediately from the heavenly bodies, or from the azure of the sky, or from the thousand brilliant hues with which the setting or the rising of the sun illuminates its attendant clouds.

In illustration of the principle just advanced, gold and silver among metals might be opposed to lead and iron: and, among flowers, the brilliancy of the crocus, the lily, or the rose, to the lurid aspect of henbane or belladonna. And though something of a moral character may in these instances determine the preference; yet there is nothing unreasonable in supposing, that, as the instincts of the inferior animals regulate their tastes and distastes to natural objects; so there may also be in the case of human beings congruities, or the reverse, between the sense impressed and the object impressing it. In fact, with respect to that sense, the organ of which is the ear, it is known that infants shrink back from deep sounds, and express delight at acute sounds, long before any intellectual or moral feeling can sway them; and, correspondently with this assertion, the lullaby of the nurse partakes, among all nations, of the same essential character. It is a fact equally deducible from observation, that particular flavours and odours are naturally acceptable, or the reverse, to children. And again, with reference to the sense of touch, smooth surfaces almost universally give a pleasing impression; which is not imparted by rugged surfaces. Why then may it not be the same with respect to the sense of sight, in the case either of colour or of form?

The abundant supply of light from its natural source the sun, and the ease with which it is producible by artificial means during the absence of that luminary, render us habitually less sensible of its real value, than undoubtedly we should be, were we to experience a long continued privation of it. And as to the regularly periodical privation of it which we experience in consequence of the alternation of night with day, this is so far from being an evil, that it is obviously beneficial; inasmuch as, in consequence of this very absence, sleep is both directly and indirectly conciliated: without which gift of Heaven, all our faculties would soon be exhausted, and all our happiness consequently extinguished.

The beneficial influence of sleep on our whole frame is too obvious in its effects to require any formal demonstration: but it will be interesting to consider its relation to the absence of light. It appears then that, by a fundamental law of our nature, a sense of uneasiness invariably follows a long continued exercise of our powers,

either corporeal or mental: and, unless this sense of uneasiness have been produced by too inordinate exercise, it is soon relieved by that state of the system which we call sleep; during the continuance of which, provided it be sound and of a perfectly healthy character, all the voluntary muscles of the body become relaxed, and the nervous system remains comparatively inactive; the whole body acquiring by this temporary cessation of its energies a renovated accumulation of those powers, which are necessary for the purposes of active and intellectual life.

In order to dispose us to yield to the sensation of approaching sleep, the periodical succession of night to day has been ordained by nature. For, with the approach of darkness cease all the usual stimuli of that sense, which is accommodated to the impulse of light, and which calls our faculties into action more frequently than any other: nor is the intention of nature less evident, because, either from avarice or the dissipation of luxury, some individuals protract the labours or the pleasures of the day beyond the natural period assigned for those purposes; since these are unnatural exceptions to the observance of the general law.

Although it would be difficult to prove directly that there is any necessary connexion between darkness and sleep, yet this connexion is rendered at least highly probable by the effect usually produced on the approach of darkness upon animals in general, but more remarkably on birds; for, with the exception of those whose habits are nocturnal, all birds betake themselves to sleep as soon as night approaches: and if darkness should anticipate night by many hours, as happens when any considerable eclipse of the sun takes place in the middle of the day, we still find the birds of the field as well as our domesticated fowls give the same indications of composing themselves to sleep, as at the regular period of sunset. If it should be said that this does not more serve to prove a connexion between darkness and sleep with reference to these animals, than to prove the effect of a long continued association resulting from their habit of going to roost at sunset; it may be asked, why should darkness, unless from some inherent cause, lead them to compose themselves to sleep at the hour of noon, instead of the usual hour of evening; since, on the one hand, periodical states of the animal system do not usually recur before the termination of the habitual period; and, on the other hand, the individuals cannot at so early an hour have experienced such a degree of exhaustion as would of itself invite to sleep?

In stating that the voluntary action of the muscles ceases during sound sleep, we ought not to omit the remarkable fact that those muscles which are not under the empire of the will continue their action uninterruptedly through the deepest sleep. Of all the muscles of involuntary motion, this observation holds most remarkably with respect to the heart; the continued action of which organ during

sleep is a phenomenon worthy of the deepest attention of a philosophical mind. All other organs of the body have their periods either of absolute or comparative rest; the senses are in a measure periodically locked up by sleep during one quarter at least, if not one third of our whole existence; the limbs of the most athletic individual lose their power of motion after a few hours of unremitted exertion: even the brain, which during the hours of sleep and the interruption of all the common functions of the body frequently represents to the internal senses the most busy scenes of active life—even the brain may be exhausted by unusual fatigue, or other causes, and may thus involve the general system in the stupor of apparent death—but the heart, unless on such occasions as the momentary interruption of a swoon, never rests: so that, whether we look back to that period of our existence, when, in our yet imperfect state, there could scarcely be discovered the faint outline of those members, which in after life constitute man's strength and beauty, the presence of the heart may be recognised by the impulse of its vibratory motion, though its form is yet undefined, or at least indistinguishable; or whether, on the other hand, we look forward to the latest moments of protracted disease, or expiring old age, the same organ is the last part of our frame which continues to give immediate proof of vital motion.

The privation of light is rarely, if ever, total: for though the empire of time is divided in nearly equal proportion between day and night, there are comparatively few nights in which there is not diffused through the air a sufficient quantity of light for many of the purposes of life. Nor, with respect to those persons who either were born blind, or became blind in early infancy, is the absence of light felt with any degree of severity; for, in such instances, although the individual may be made to understand that he wants some faculty which those around him possess, there cannot be however any consciousness of privation where there never had been actually any enjoyment; or where there was no recollection of it, if it had for a time existed. And even in the case of individuals who have been deprived of sight long subsequently to birth, although the recollection of the former enjoyment must more or less imbitter their present state; yet so long as the offices of surrounding friends are the means of administering to their comfort, more especially if those offices are fulfilled with kindness, the mind soon becomes reconciled to the privation: for it is a fact, repeatedly observed, that blind persons under such circumstances are usually cheerful. Nor ought we to forget the compensation which nature affords to those who are deprived of sight, in the consequently quickened activity of some of the other senses.

Let us however suppose for a moment that, all the faculties and recollections of man remaining unaltered, and the general processes of nature continuing, if possible, the same as they are now, the ex-

istence of light were withdrawn from this earth: what would then be the condition of mankind? How could those occupations of life be pursued which are necessary for the supply of our simplest wants? Who in that case should yoke the ox to the plough, or sow the seed, or reap the harvest? but indeed under such a supposition there would soon be neither seed for the ground, nor grain for food: for, if deprived of light, the character of vegetation is completely altered; and its results, as far as general utility is concerned, destroyed. Or suppose, further, that these necessary supplies of life were no longer required, on account of some consequent alteration in our physical constitution; or that they were procured for us by any unknown means; yet, in all the higher enjoyments of our nature, how cheerless, how utterly miserable would be our situation. Under such circumstances, wisdom would not only be

"at one entrance quite shut out,"

but no other entrance could then be found for it; for of the other senses, the only remaining inlets of knowledge with reference to an external world, there is not one, which, if unaided by sight, could be of any practical value. With respect indeed to our inward feelings, though we should, on the one hand, be spared, by the privation of light, the worse than corporeal pain of the averted eye of those who ought to meet us with gratitude and affection; we should, on the other hand, lose the beams of filial or parental love; of which even a momentary smile outweighs an age of pain.

As in mathematical reasoning the truth of a proposition is sometimes indirectly proved by showing that every process of proof but the one proposed would lead to an absurd conclusion: so, though the supposition of a general and total privation of light is on all probable grounds of reasoning inadmissible, it may yet serve to show us indirectly the value of the good we enjoy. But it is sufficient to have given a few instances of the necessary effects of such a privation: and it will be a more grateful task to enumerate the actual benefits which we derive from the agency of light.

In the vegetable world, upon the products of which animal existence ultimately depends, light is the prime mover of every change that takes place, from the moment the germ emerges from the soil. Exclude the agency of light, and in a short time the most experienced botanist might possibly be at a loss to know the plant with which he is otherwise most familiar; so completely obliterated are all its natural characters, whether of colour, form, taste, or odour. Thus the faded colour of the interior leaves of the lettuce and other culinary vegetables is the result of such a degree of compression of the body of the plant as excludes the admission of light beyond the exterior leaves. And, again, if a branch of ivy or of any spreading plant happen to penetrate during the progress of its vegetation into a dark cellar, or any similar subterraneous situation, it is observable, that, with the total loss of colour, its growth advances with great

rapidity but its proportions alter to such a degree as often to mask its original form. And, lastly, which in a practical point of view is of the greatest importance, if a plant which has grown without the influence of light be chemically examined, its juices, it might almost be said its whole substance, would be found to consist of little else than mere water; and, whatever odour it may have, is characteristic, not of its original nature, but of its unnatural mode of growth; becoming, in short, very like that of a common fungus. The total result is, that all the native beauties and uses of a vegetable growing under these circumstances are lost: the eye is neither delighted by any variety or brightness of colour; nor is the sense of smell gratified by any fragrance: the degeneracy of its fibre into a mere pulp renders it unfit for any mechanical purpose; and the resinous and other principles on which its nutritive and medicinal virtues depend, cease to be developed. In some instances, however, the bleaching or *etiolation* of plants is useful in correcting the acrid taste which belongs to them in their natural state; as in the case of endive and of celery.

The effect of light upon vegetation has been selected in the preceding paragraph as affording the most powerful instance of the adaptation of this natural agent to the physical condition of man. Its effects upon individuals of the mineral and animal kingdom are neither so easily to be traced, nor are nearly so important in their consequences, at least in a practical point of view; and therefore it is not proposed to bring them forward in a more particular manner.

The observation of those modifications which light undergoes when reflected from the surfaces of bodies has given rise to one of those impressive arts which are capable of contributing no less to the refinement of society at large, than to the gratification of the individuals who cultivate or admire them. For who can look on the productions of such masters as Guido, Raphael, or Michael Angelo, without imbibing a portion of the spirit which animated those masters in the execution of their inimitable works? or, if we quit the regions of imagination and of history, and descend from the higher efforts of the art into the retirement of domestic life, who can successfully describe those emotions which are excited by the portrait of a beloved object, a child or parent now no more; or by the representation of that home and its surrounding scenery, in which the careless and happy hours of childhood were passed?

The intrinsic source of the pleasure which we experience from the contemplation of a painting is probably to be sought for in that principle of our nature, of more extensive influence perhaps than is generally supposed, which derives a gratification from perceiving the resemblance of actual or probable truth; or even, and sometimes in a higher degree, from the delineation of fictitious characters and scenes: and hence the art of painting is easily made the vehicle of the ludicrous and the horrible, no less than of the sublime and the

beautiful: and, hence also, the painter, may incur a considerable degree of moral responsibility in the exercise of his art. But this view of the subject, though fertile in reflections of great moment, and practically too much neglected, does not belong to the purpose of the present treatise.

Section III.

Heat.

From the consideration of the subject of light, the mind passes by a natural transition to that of heat: for these agents, though not necessarily or always, are in reality very often associated together: and they are each of them characterised by the want of that property which almost seems essential to matter, namely weight. In their relation to the physical existence of man and animal life in general, there is this difference between them—the presence of light is only indirectly necessary; the presence of heat is directly necessary. Different degrees of heat indeed are requisite for different species of animals: but if the heat to which any individual animal be exposed be much below that which is natural to the species, and be continued for a sufficient length of time, all the vital functions are eventually destroyed; or, as in the case of the hibernation of particular species of animals, are at least partially suspended.

The degree of heat adapted to the human frame is so nicely adjusted to the bodily feelings of man, that, if we take a range of fifty degrees of Fahrenheit's thermometer as indicating the average extent of variation to which the body is exposed in this climate, it will be found that a difference of two or three degrees, above or below a given point, will generally be sufficient to create an uncomfortable sensation. The late Mr. Walker, whose experiments on the artificial production of cold are well known to the philosophical world, ascertained that the point of 62° or 63° of Fahrenheit is that, which, upon an average of many individuals, is in this climate the most cogenial, as far as sensation is concerned, to the human body. But it is a merciful provision of nature, considering the numerous vicissitudes of human life, that man is capable of resisting very great and even sudden alterations of temperature without any serious inconvenience. Thus an atmosphere so cold, as to depress the mercury in Fahrenheit's thermometer to the 52d degree below the freezing point of water, has been borne under the protection of very moderate clothing. And, on the other hand, an atmosphere of a temperature as high as the 200th degree of Fahrenheit, which is within a few degrees of the boiling point of water, was borne by the late Dr. Fordyce, during ten minutes.* And it is highly worthy of notice, as

* Phil. Trans. 1775. vol. lxv. p. 117.

connected with the general intention of this Treatise, that, during the same time, a thermometer which had been fixed under his tongue indicated only the 98th degree of Fahrenheit:* so that the body remained very nearly of its natural temperature, during its exposure to an atmosphere exceeding its own temperature by full 100 degrees.†

This uniformity of animal temperature, under such circumstances, is in a great measure owing to the process of evaporation, which takes place from the general surface of the body, and from the air-vessels of the lungs: for if animals are confined in a chamber, the atmosphere of which is so moist that no evaporation can take place from the surface of their bodies, it has been found that their temperature is as capable of being steadily and uniformly raised, by increasing the heat of the room in which they are placed, as if they were inanimate matter.

The application of heat to the various purposes of life has a very extensive range; and with reference to the daily preparation of the more common forms of our food, whether animal or vegetable, distinguishes the habits of man from those of every other species. Without the power indeed of commanding the application of heat in its various degrees, many of the most important arts of civilized society would fail.

Without that power, how could clay be hardened into the state of brick, of which material most of the habitations in many large cities are constructed? Without the aid of the same agent, how could quicklime, the base of every common cement, be produced from limestone? Without the application of the higher degrees of heat, metals could neither be reduced from their ores, nor the reduced metals be worked into convenient forms. Neither, without the same aid, could that most useful substance glass be produced; a material, which in comparison hardly known to the ancients, has in modern times, be come almost indispensably necessary to persons of the poorest class, as a substance of daily use for various economical purposes. But if we consider the properties of this valuable compound, with reference to the aid derived from it in the investigations of science, there are few substances of higher importance to the philosopher. Among the most useful of those properties are its impermeability to fluids, either in a liquid or aeriform state; its ready permeability to light, together with its power of modifying the qualities of that fluid; and its resistance to almost all those chemical agents, which are capable of destroying the texture of most other substances with which they remain long in contact.

In considering the extensive utility of the thermometer, and barometer, in their common and most convenient forms, it is evident that

* Ibid. p. 118.

† For an account of similar experiments carried to a further extent, see p. 484, &c. of the same volume of the Phil. Trans.

their practical value almost entirely depends on the transparency of glass, and on its impermeability to air: for if the glass, of which they are made, were opaque, the variations in the level of the quicksilver contained within them would be imperceptible to the eye; and could not be indirectly ascertained, unless by very circuitous and difficult means: and, on the other hand, if the glass were permeable to air, the variation in the level of the quicksilver, in the case of the barometer at least, would necessarily be prevented. The same properties of transparency and impermeability to air very greatly enhance, if they do not solely constitute the value of glass, in all those philosophical experiments which are carried on under what is called the exhausted receiver.

But the most important result of the transparency of glass is the modification which light undergoes in its passage through lenticular masses of that material. When, for instance, in consequence of disease or advancing age, the eye no longer retains the power of discerning objects distinctly, how much of hourly comfort, as well as of intellectual enjoyment, would be lost, were we not able to supply the natural defect by the artificial aid of glasses of the requisite form and density. And, again, how many important facts in the physiology of animals and vegetables, as also in the constitution of inanimate bodies, would have remained for ever undiscovered, but for the aid of the microscope; the magnifying powers of which depend on the transparency, and form, and the right adjustment of those pieces of glass through which the objects subjected to observation are viewed?

And, lastly, how shall we estimate the value of those discoveries, to say nothing of the constantly accumulating mass of observations connected with them, which the world owes to that wonderful instrument the telescope? By the aid of which not only has the knowledge of our own sidereal system been extended, in consequence of the discovery of new planets belonging to it; but it seems to have been rendered highly probable that those obscurely defined luminous masses, which Sir William Herschel termed *nebulæ*, observable within the limits of individual constellations, are really the accumulated light of innumerable stars seen through the medium of a space hitherto immeasurable: and that the *milky way* itsely is an extended accumulation of similar nebulæ; the collected light of which, at some inconceivable point of distance, may appear to the inhabitants of still more distant spheres, as a mere speck. Dare the mind attempt to penetrate beyond this general statement, and to speculate upon the characters of its detail? What if there be a resemblance, or even an analogy, between the structure and inhabitants of this earth and of the other planets of our system? What if every fixed star which we either see with the naked eye or by the aid of the telescope, or whose existence we can conceive on probable grounds by the mind's eye, be itself the centre of a system consisting, like our own, of numerous subordinate

spheres, and every one of these inhabited by responsible agents, like ourselves; to whose uses both inorganic elements and animals and vegetables, analogous if not similar to our own, may be subservient? What if the moral history and state of the inhabitants of those numberless spheres be like that of man?—But the view, which the investigation of this question seems capable of unfolding, is too awful for the eye of reason; and, however its discussion might magnify our conviction of the infinite power and goodness of the Creator, is not to be approached perhaps without culpable presumption.

Let us therefore return to considerations more appropriate to the character of human knowledge: and, having referred to the effects produced by heat on various forms of matter, let us inquire what facilities nature has placed within our reach for the purpose of exciting and maintaining heat itself. The chemist in his laboratory, surrounded by the numerous and various agents which he is constantly employing, can never have any difficulty in producing the vestal element. By concentration of the sun's rays he may inflame any combustible substance: by compression of common air in a small cylinder of glass, or metal, he may ignite a piece of fungus, or inflame a piece of phosphorus, attached to the extremity of the piston which is employed to compress the air. He may instantaneously produce flame by pouring concentrated nitric acid on oil of turpentine, or on certain saline compounds; by the simple trituration of phosphorus, or other chemical agents; by directing a small stream of inflammable air on minute particles of platina loosely aggregated in a state somewhat resembling sponge; or, not to accumulate too many instances, he may delight himself for the thousandth time by igniting a fine wire of steel, in passing the electric current along it by means of the Voltaic apparatus.*

There are few individuals however who have commonly such magic instruments at hand: and, even if they had, it is probable that

* It will not perhaps be deemed impertinent, to relate an instance of the sagacity of the late Dr. Wollaston, in connexion with the present subject. It happened to the author of this Treatise, at a comparatively early period of his life, to deliver a letter of introduction to Dr. Wollaston at a moment when that philosopher was engaged in conducting an electric current, by means of the Voltaic apparatus, through three portions of fine steel wire, different from each other in diameter. With that vivacity of manner, which in him resulted rather from the simple consciousness of the acquisition of truth, than from the ignoble triumph of individual superiority, he asked which of those wires would first become of a red heat; and being answered, at a hazard rather than from any reasonable ground of conjecture, that the red heat would perhaps first take place in the thickest of the three—"I expect it will," he said, "and that the finest wire will never reach a red heat; for I conclude that, from its extreme fineness, the heat excited in it will be dissipated by radiation so rapidly, as to prevent the accumulation of a quantity sufficient for its ignition." It need hardly be added that the conjecture was verified.

As an instance of the minute scale on which Dr. Wollaston was in the habit of carrying on his philosophical investigations, it may he mentioned that the preceding experiment was conducted in a single cell of a single and moderately sized Voltaic trough.

they would want both the leisure and inclination to preserve them in a state fitted to produce at any moment the intended effect; for, though each successive year has of late given birth to some new form of apparatus calculated to produce instantaneous light, we find ourselves constantly recurring to the flint and steel, which our forefathers of many generations have used; and which will doubtless be the staple apparatus of our latest posterity.

The more important part of the present inquiry remains to be considered, the means namely of maintaining heat, when once excited, to a sufficient extent and degree of intensity for the various purposes of social and civilized life. To this important purpose, among others, the products of the vegetable world, both in a fossil and recent state, are destined; and in examining the origin and general history of some of these products, particularly with reference to common coal, we shall meet with an interesting example of those provisions of nature which Dr. Paley has denominated prospective contrivances.

In the early periods of civilization, and while the population of a country bears a small proportion to the extent of soil occupied, the indigenous forests easily supply an ample quantity of fuel: or in the absence of those larger species of the vegetable kingdom which may be described under the term of *timber*, the humblest productions of the morass, though not the most desirable, are however a sufficient substitute. Thus the *sphagnum palustre* and other mosses, by their successive growth and decay, form the combustible substratum of those extensive and at present uncultivated tracts in Ireland, which, till they shall have happily been reclaimed by the industry of a yet barbarous population, contribute by the turf and the peat which they afford, to the comfort of myriads of individuals; who, were it not for this source of supply, would be, in their present state, in total want of one of the principal necessaries of life.

In many populous districts of this island, the aboriginal forests, which formerly so amply supplied the surrounding inhabitants, have long since been cleared from the surface of the earth: and their site is now occupied by cultivated lands and a condensed population. The former source of fuel has consequently in such parts long since failed: but the clearing of the surface has in many places detected that invaluable mineral combustible, which, usually bearing in itself indubitable marks of a vegetable origin, from the traces of organization still apparent in almost every part of its substance, was deposited ages before it was wanted, as a future substitute for the fuel which in the meantime has been derived from the actually existing vegetable kingdom.

It is not intended here to enter into the general consideration of those geological formations called *coal fields*, which are the repositories of this useful mineral: but there is one circumstance in their history so evidently calculated to facilitate the labour of man in obtaining this substance, and to extend its supply, and so remarkably

though not exclusively characteristic of those particular formations, that though not obvious to a general observer, it cannot fail to arrest the attention of those to whom it is pointed out. A coal field may be represented, in a popular description, as consisting of a succession of alternating strata of coal and sand-stone, &c.: which, having been originally deposited in a basin-shaped cavity, in such a manner as to be at the same time parallel to the concave surface of the basin and to each other, have been subsequently broken up by some force that has thrown the planes of the ruptured masses into various directions. Now, had the strata remained undisturbed, a very considerable proportion of the coal which is now quarried would most probably never have been obtained by human industry: for, the strata dipping down from the circumference towards the centre of the basin, that perpendicular depth, beyond which it is practically impossible to work the coal, would soon have been reached in the operation of mining. But, in consequence of the rupture and consequent dislocation of the strata, many of those portions which were originally deposited at such a depth beneath the surface as would have rendered the working of them impossible, have been thrown up to the very surface; and thus have become available to the miner.

Section IV.

The general Uses of Water.

One of the earliest political punishments of ancient Rome affords an indirect but very remarkable proof, of the immediate importance of the elements of fire and water* to human life: for this punishment consisting, in part, in an interdiction from the use of water, compelled the individual so punished to fly from his native neighbourhood, in order to obtain that necessary article of support elsewhere: and, hence, banishment and interdiction from fire and water became synonymous terms. There are few who have not experienced the uneasy sensation occasioned by even a temporary privation of this necessary: and the death that ensues upon a continued privation of it is, perhaps, of all modes of death the most dreadful. This we learn from the occasional accounts of individuals who have escaped from shipwrecks, in which their companions had perished

* An apology will hardly be required for applying the term *element* to a substance, which though it has long been experimentally ascertained to be a compound, will in a popular view be always considered as a simple body; especially if it be remembered that even among the ancients this term did not necessarily imply that the substance so called was absolutely a simple or uncompounded body. It was sufficient with them, that, in all the known processes and phenomena of nature, the substance presented itself under the same essential form: but they were prepared to allow that elementary bodies (στοιχεῖα) might possibly be resolved into absolutely simple principles (ἀρχαί).

amidst the agonies of thirst. And it is said of those unhappy victims of a barbarous punishment, in Persia, (who being immured in masonry, as to every part of their body but the head, are left to perish in that state,) that they terminate their last hours, perhaps days, in incessant cries for water.

The necessity of this element for our support may be antecedently inferred, on philosophical principles, from the examination of the physical composition of any animal body; of which, in by far the greater number of instances, more than three-fourths of the whole weight are due to the presence of water. This water of composition may be easily separated by the application of a moderate degree of heat, or even by spontaneous evaporation at a common temperature, without any further decomposition of the body; the muscles and skin consequently shrinking to such an extent, so as to give the whole frame the appearance of a skeleton, enveloped, as it were, in parchment. Such a result is occasionally observable in human bodies which have been deposited in dry cemeteries; and is by no means uncommon in the case of small animals, as rats, for instance, which having been accidentally wedged in between a wall and a wainscot, are subsequently found in the state above described.

An experiment of a very simple character in itself, and very easily made, will serve to ascertain, not only the proportional quantity of water of composition contained in some forms of animal matter, but also the properties communicated by the presence of that element thus combined. Every one has noticed the opaline or milky appearance and the remarkable elasticity of cartilage, or gristle, as it is more commonly called: which characters depend on the water contained in it; for if a piece of gristle, the weight of which has been previously ascertained, be exposed to the air of a warm room, it will at the end of a few hours have lost a portion of its weight; and will have become nearly transparent, and entirely inelastic: and if, in this state, it be immersed in water, it will gradually recover its original weight, and also its elasticity and opaline appearance. If, instead of gristle, a piece of boiled white of egg be employed, the same results will be observable; for, together with loss of weight and elasticity, it will become brittle, and nearly as transparent as pure amber: and on the other hand, by subsequent immersion in water, its original properties will be soon restored. By experiments nearly as simple as those above-mentioned it may be demonstrated, that all the liquid and solid parts of an animal, with some few exceptions, contain or consist of more than three-fourths of their weight of water: the importance of which element in the mere composition of our body is hence directly evident.

But if we would have a familiar illustration of its importance in the daily and hourly occurrences of life, let us in imagination accompany an individual of moderate rank and condition in society,

from the time of his rising in the morning till the hour of sleep at night, in order to observe the utility of water in administering either directly or indirectly to his various wants and habits. How great is the comfort, to say nothing of the salubrity of the practice, which results to him from the application of water to the surface of the body, by means either of the bath or any simpler process! and, again, the change in the linen in which he is partially clothed is rendered equally comfortable and salutary, in consequence of its having been previously submitted to the process of washing. The infusion of coffee or of tea, which is probably an essential part of his earliest meal, could not have been prepared without water: neither could the flour of which his bread consists, have been kneaded; nor the food of his subsequent meal, the broths and most of the vegetables at least, have been rendered digestible, without the aid of the same fluid; and with respect to his common beverage, whether milk, or any form of fermented liquor, water still constitutes the main bulk of that beverage.

So far the use of water is directly and immediately necessary to his comfort and subsistence: but its indirect and remote necessity is equally observable in all that surrounds him. There is scarcely an article of his apparel, in some part of the preparation of which water has not been necessarily employed; in the tanning of the leather of his shoes; in the dressing of the flax of which his linen is made; in the dyeing of the wool of his coat, or of the materials of his hat. Without water the china or earthen cups, out of which he drinks, could not have been turned on the lathe; nor the bricks, of which his house is constructed, nor the mortar by which they are cemented, have been formed. The ink with which he writes, and the paper which receives it, could not have been made without the use of water. The knife with which he divides his solid food, and the spoon with which he conveys it when in a liquid form to his mouth, could not have been, or at least have not prohably been formed, without the application of water during some part of the process of making them.

By water the medical principles of various vegetable and mineral substances are extracted, and rendered potable; which could not be introduced into the animal system in a solid state: and this element itself becomes occasionally a most powerful medicinal instrument by its external application, in every one of its forms; whether as a liquid, under the name of the cold or warm bath; or in the form of ice, in restraining internal inflammation and hemorrhage; or in the state of steam, as in the application of the vapour bath.

Section V.

Baths.

The custom of bathing, whether in a medium of a high or of a low temperature, appears to be in a great measure derived from the gratification of a natural feeling: for we find it prevalent in every country and in every stage of society, not only with reference to its medicinal effects, but as a mere luxury. Thus at every season of the year, when the sky is serene at least, the inhabitants of hot climates plunge into their native streams for the sake of the refreshment imparted to the surface of their bodies; and the same refreshment is equally sought by the natives of colder climates during the heat of their short summer: in each of which instances the pleasurable sensation is the principal motive for the practice. But on some occasions a more permanent good is sought; and the hope of immediate pleasure is so far from being the motive that a sensation very nearly allied to pain, and in many instances less tolerable than pain itself, is encountered in the shock of the cold bath, with a view to the preservation or restoration of health. It may be said perhaps that the glow of warmth which usually succeeds this shock is in itself a pleasure; as indeed it is: but it may be presumed that very few individuals experience any pleasure from the shock itself, or would consent to encounter it but for its pleasurable and beneficial consequences.

For the enjoyment of the cold bath nature affords the immediate resource of springs and rivers, in almost every part of the world; but the enjoyment of the warm bath is in general not easily attainable; warm springs being comparatively of rare occurrence: the pleasure of the warm bath however is so congenial to man's feelings, that it is sought for by savages as well as by the inhabitants of the most luxurious cities; and is as acceptable in tropical as in cold climates.

It is at all times interesting to contemplate the expedients which human ingenuity discovers for the accomplishment of its purposes: but such a contemplation is more particularly interesting when it developes the revival of a principle, the knowledge of which had been buried during many centuries of intervening ignorance; and thus justifies the reflection of moral wisdom:

"Multa renascentur, quæ jam cecidere."

"The thing that hath been, it is that which shall be; and that which is done is that which shall be done: and there is no new thing under the sun."

In a most amusing and instructive account of Pompeii, which forms one of the volumes published under the name of the Library

of Entertaining Knowledge, is a dissertation on the Baths of the Ancients; which will amply repay, by the information it conveys, the time occupied in its perusal. In that dissertation is contained a description of the remains of some public baths, discovered in the excavations of Pompeii: and with reference to the disposition of the furnace of the baths, a fact is stated, which is peculiarly applicable to our present purpose.

It is evident that, in consequence of the enormous quantity of water which was daily heated in their public baths, the attention of the ancients must necessarily have been directed to the most economical mode of applying the fuel by which the heat of the furnace was maintained: and the following extract from the above mentioned account of Pompeii will show that, even in a small town of ancient Italy, an economical principle was well understood and applied eighteen centuries since, which has only been of late revived in modern science. It is stated in that account (p. 152), that "close to the furnace, at the distance of four inches, a round vacant space still remains, in which was placed the copper for boiling water (*caldarium*); near which, with the same interval between them, was placed the copper for warm water (*tepidarium*); and at the distance of two feet from this was the receptacle for cold water (*frigidarium*). A constant communication was maintained between these vessels; so that as fast as hot water was drawn off from the caldarium, the void was supplied from the tepidarium, which, being already considerably heated, did but slightly reduce the temperature of the hotter boiler. The tepidarium in its turn was supplied from a general reservoir: so that the heat which was not taken up by the first boiler passed on to the second; and, instead of being wasted, did its office in preparing the contents of the second for the higher temperature which it was to obtain in the first. It is but lately that this principle has been introduced into modern furnaces; but its use in reducing the consumption of fuel is well known."

In the same account of Pompeii is afforded a striking instance, with reference to the vapour bath, not only of the similarity of the means employed for producing a similar effect, by individuals between whom no communication can be traced or even supposed; but also a similarity of custom, with reference to the enjoyment of social intercourse, between communities not less widely separated from each other by time and space, than by degree of civilization; between the luxurious inhabitants of imperial Rome eighteen centuries ago, and the savage tribes of North-western America at the present day. The author of the account of Pompeii states (p. 187—190,) on the authority of Tooke's Russia, "that the Russian baths, as used by the common people, bear a close resemblance to the vapour bath (*laconicum*) of the Romans. They usually consist of wooden houses, situated, if possible, by the side of a running stream. In the bath-room is a large vaulted oven, which, when heated, makes

the paving stones lying upon it red hot; and adjoining to the oven is a kettle fixed in masonry for the purpose of holding boiling water. In those parts of the country where wood is scarce, the baths sometimes consist of wretched caverns, commonly dug in the earth close to the bank of some river. The heat in the bath-room is usually from 104° to 122° of Fahrenheit; and may be much increased by throwing water on the glowing hot stones in the chamber of the oven. The Russian baths therefore are vapour-baths; and it appears that even the savage tribes of America are not wholly unacquainted with the use of the vapour-bath. Lewis and Clarke, in their voyage up the Missouri, have described one of these in the following terms: 'We observed a vapour-bath, consisting of a hollow square of six or eight feet deep, formed in the river bank by damming up with mud the other three sides, and covering the whole completely, except an aperture about two feet wide at the top. The bathers descend by this hole, taking with them a number of heated stones, and jugs of water; and, after being seated round the room, throw the water on the stones till the steam becomes of a temperature sufficiently high for their purposes.'"*

It appears then, from the foregoing statement, that the peasants of Russia, and the savages of North America, are in the habit of employing the same means for converting water into vapour, which were employed by the Romans at the most luxurious period in their history: and to the peasants of Russia and the savages of North America, may be added the natives of New Zealand and other islands of the Pacific ocean; merely with this qualification, that they employ the steam, so raised, not for the purpose of a vapour-bath, but of dressing their food.

It is worthy of notice, as illustrative of the social feeling inherent in human nature, that, equally among the uncivilized natives of America as among the luxurious inhabitants of ancient Italy, "it is very uncommon for an individual to bathe alone; he is generally accompanied by one, or sometimes several, of his acquaintance: bathing indeed is so essentially a social amusement, that to decline going in to bathe, when invited by a friend, is one of the highest indignities that can be offered to him." (p. 190.)

Section VI.

The Fluidity of Water.

Familiarized as we are to the consequences resulting from that property of water, whereby its particles move so easily among them-

* Sauer, in his account of Billings' expedition, describes the same kind of bath as used in north-western America (p. 175.)

selves as to yield to the least impulse, provided there be space for yielding, we rarely perhaps meditate on its importance: and yet it is entirely owing to this property that a free communication is capable of being maintained between distant parts of the world by means of the ocean at large, and between different parts of the same country by means of navigable rivers; or by those more than rivals of navigable rivers, artificial canals.*

Rarely also, perhaps, do we meditate on the equally important fact, that, throughout the greater part of the world this element usually exists in a liquid state: and important indeed is that fact; for, of the three states under which it is capable of existing, namely of ice, water, and vapour, if its predominant state had been that of ice or of vapour, philosophers might possibly have conjectured, but the world could never have seen realized, the mighty results of commerce as depending on the art of navigation.

From the same physical character of water, above described, namely its fluidity, manifesting itself actively instead of passively, are daily produced results of equal importance to society, and equally surprising in themselves. Who indeed can adequately describe the advantages derived from water in aiding the powers of mechanism, from the half-decayed and moss-grown wheel that scarcely sets in motion the grinding-stone of the village mill, to the astonishing momentum of the steam engine which kneads a hundred tons of heated iron with as much ease as the hands of the potter knead a lump of clay!

And here, since it is of the utmost importance to mankind that this element should usually exist in a liquid state, let us pause a while to investigate the means employed by nature to prevent its rapid conversion either into vapour or into ice. For although its partial existence in both those states is perhaps eventually as necessary to the general good of the world as its more common state of water, yet, if its sudden or rapid conversion into either were not prevented, great temporary evil would necessarily ensue from our privation of it as a liquid.

It has been already mentioned that the atmosphere constantly holds in solution or suspension a great body of water, in a state of minute division: but the quantity that can be carried up into the atmosphere by the process of evaporation is limited in two ways; first, by the air's incapability of holding in suspension more than a certain proportion; and secondly, by the restraining effect of the pressure of the atmosphere. But the rapid evaporation of water is also prevented by the comparatively low temperature at which all its natural forms exist, even in tropical latitudes.

* It has been stated, on credible authority, that an agent of a great proprietor of canals being incidentally asked, during a legal examination, for what purpose he conceived rivers had been made, answered, "that, no doubt, they were intended to feed canals."

The prevention of the sudden conversion of water into ice depends on a peculiarity in its physical constitution, which is no less remarkable in a simply philosophical point of view, than beneficial in its result to the great bulk of mankind. Water, in common with all other forms of matter, is gradually contracted in its volume by a dimunition of its temperature; and ultimately passes into a solid state. It does not however continue to be condensed to the moment of its congelation, but only to a certain degree of temperature; from whence it begins to expand; and continues to expand till it arrives at the point of congelation.

In this deviation from a general law we find a very beneficial accommodation to the wants of man: for had it been the property of water to become more and more condensed as it approached the point of congelation, one of the consequences would have been that lakes and rivers, instead of becoming gradually frozen from the surface towards their bed, would almost in a moment have become one solid mass of ice: and the evil that would be produced by such an effect may be conjectured, by considering that whenever a long protracted and severe frost has thickened to an unusual extent the superincumbent stratum of ice, the difficulty of breaking through the stratum, in order to arrive at the water beneath, is proportionally increased, and sometimes becomes practically insuperable.

It will be interesting to trace the steps by which this providential law of nature is manifested: and the whole process is easily rendered intelligible to any one who will simply bear in mind these three points, namely, that the average temperature of lakes and rivers is during the heat of summer more or less above the 40th degree of Fahrenheit's scale; that water itself at about the 40th degree is of its greatest density; and that under all common circumstances it freezes, or becomes solid, at the 32d degree. If we suppose then the temperature of a pool or lake to equal at any given moment the 50th degree of Fahrenheit; and a gradual reduction of its temperature to take place from that moment by the effect of a constantly diminishing temperature of the air; under such circumstances the following phenomena would occur. The particles of the water at the surface becoming more condensed, that is heavier, as they become cooler, would sink towards the bottom, and be replaced by the hitherto subjacent particles; which in their turn, undergoing a similar decrease in their temperature and condensation, would consequently subside towards the bottom; till at length the whole mass of water had arrived at the temperature of about 40°. From this point any progressive decrease of temperature would have an expansive effect upon the particles of water near the surface; which, being thus rendered relatively lighter than the particles of the subjacent mass, would not subside; but, remaining on the surface, would continue to be expanded and made still lighter till they had reached the temperature of 32°; at which degree, under ordinary circumstances, they would freeze. But the

coat of ice thus formed would be, in some measure, a barrier to the effect of the colder atmosphere upon the bulk of the water beneath; which consequently would remain for a comparatively longer time in a liquid state; and would be easily procured for general purposes, by making partial openings through the frozen surface. Now if the density of water continued to increase in a regular progression to the moment of congelation, it would necessarily happen, from the sinking of the particles gradually thus condensed, that at some given moment the temperature of the whole mass, still in a liquid state, would have arrived at the freezing point; and consequently the whole mass would have been frozen, or become solid, at the same moment. The possibility of such a simultaneous congelation is not merely a philosophical deduction, it sometimes actually occurs. Thus, under certain circumstances, particularly if kept entirely free from agitation, water, still retaining its liquid form, may be cooled down to a point several degrees below that of congelation; when, upon a slight agitation, the whole mass is converted at once into the state of ice.

Section VII.

The natural Sources of Water.

For the supply of a substance of such immediate necessity to the very existence of man, and of such extensive utility in promoting his comforts, nature has provided the amplest means; all however ultimately derived from that mass of water which has been carried up into the atmosphere by evaporation from the sea: so that if that evaporation were to fail, all forms of animal and vegetable matter, with the exception of those which belong to the ocean itself, would soon perish; for under such circumstances the earth would be deprived of those seasonable showers, without which its vegetable productions could not be sustained; and every spring would soon fail, and every river be dried up: for rivers are in most instances formed by the progressive accumulation of various torrents; and these are produced by that portion of rain which, having fallen upon the ridges and inclined surfaces of hills and mountains, descends more rapidly than the soil can absorb it: and springs result, in a manner that will be hereafter mentioned, from the accumulation of that portion of the rain which sinks beneath the surface on which it has fallen. But it is evident that if the vegetable world were to perish, the animal world could not long survive.

Nor are the laws by which the moisture, contained in the atmosphere, is precipitated from it in dews or rain, among the least admirable instances of the provision made by nature for a constant supply of the wants of man.

The mechanism, if the term be allowable, by which the formation

of clouds and the occasional descent of rain are regulated, resides in the variableness of the state of the heat and electricity of the atmosphere: in consequence of which a given mass of air is incapable of retaining, in solution or suspension, the same quantity of moisture which it did before; and hence that moisture is precipitated in the form of dews and fogs; or, being previously condensed into accumulated masses of clouds, is discharged from those clouds in the form of rain.

It almost seems puerile to illustrate the adaptation of the present laws and order of nature to the wants of man, by the supposition of the consequences that would ensue from a failure of those laws; and yet, as in actual life we often feel not the value of the good which we possess, till admonished by the prospect of its loss; so, with reference to the constitution of nature, we may more forcibly be impressed with the conviction of its general harmony and subserviency to our wants, by the supposition of its being different from what it is, than by the direct contemplation of its actual state. In supposing then that means had not been provided for the regular discharge of portions of that mass of water which has been carried up into the atmosphere by the process of evaporation, the existence of that mass would have been of little avail to man: for mere contact of an atmosphere, however moist, could not promote vegetation to any useful extent;* and the formation of springs and rivers would be as effectually prevented by rain ceasing to fall from the atmosphere, as if the material of the rain itself did not exist in it.

Of the modes in which nature disposes of the rain that has fallen on the earth, and of the formation of natural springs and rivers, more particular notice will be taken hereafter: but it may be observed by the way, that, although there is scarcely any substance which water is not capable of dissolving to a certain extent, and consequently no natural form of water is pure, yet in almost every instance the natural forms of water are not only innocuous, but salutary.

Section VIII.

The Air of the Atmosphere, as connected with Respiration.

If we suppose the atmosphere deprived of heat, and light, and moisture, and of all those other heterogeneous particles which are either naturally or accidentally contained in it; there still remains the medium which is the receptacle or vehicle of those various substances: and this medium is indeed that, which in common apprehension is understood to be the atmosphere itself.

* Niebuhr asserts, what is confirmed by other travellers, that many tracts in Egypt and Palestine, formerly well cultivated and fertile, are at present mere deserts for want of irrigation. (Descript. de l'Arabie, p. 241.)

Of the vital importance of atmospherical air no formal proof can be required; for every one capable of the least reflection must know that its presence is almost constantly necessary to the existence of man, from the moment of his birth to that of his death. Of all other external aids we may be deprived for a comparatively long time without danger, or even without much inconvenience; of light and heat for instance, and of food and sleep: but we cannot be deprived of the air which we breathe even for a very few minutes, without dreadful distress; or, if for more than a very few minutes, without the extinction of life.

This vital importance of the air depends, principally, on its capability of assisting to withdraw from the body, chiefly through the agency of the lungs, portions of that peculiar principle called *carbon;* the permanent retention of which would be incompatible with the continuance of life. And the union of this principle with one of the constituent parts of atmospherical air is probably effected in the lungs during the process of respiration; the compound passing off in the act of expiration, in the state of an aeriform fluid, called *carbonic acid gas.*

But, in order to give a clear idea of the nature of the process of respiration, it will be necessary to explain more particularly not only the constitution of that portion of the atmosphere which supports this process, but some of its chemical relations to other substances. Atmospherical air then, considering it in its adaptation to the process of respiration, consists of a mixture or combination of two aeriform fluids, which are very different from each other in character, but intimately blended together in the proportion of four to one. Of these two fluids, that which is in the smaller proportion is not only capable of supporting life, when respired or breathed alone; but is capable of supporting it for a much longer period than an equal volume of atmospherical air would have supported it: and if, instead of being employed for the process of respiration, it be made the medium of supporting combustion, the consequent phenomena are still more remarkable; for the combustible body not only burns for a longer time than it would have done in the same quantity of atmospherical air, but it burns with an intensity much more vivid; the light of the flame being in many instances too powerful to be easily borne by the eye. On the other hand, that constituent part of atmospherical air, which is in the greater proportion, not only will not support either life or flame, even for a short time, but extinguishes both, almost in an instant.

By numerous experiments, which it is at present unnecessary to describe, it has been ascertained, that many of the metals are capable of attracting and combining with this respirable part of the air: during which process the metallic body assumes an earthy character, and becomes increased in weight; while the weight of the air, in which the experiment has been conducted, becomes diminished

exactly to the amount in which that of the metal has been increased: and, at the same time, the residuary portion of the air which has been employed in the experiment equals only about four-fifths of the original volume; and is now incapable of supporting either life or flame. But, by processes well known to chemists, the metallic substance may be made to yield a quantity of air equalling that which has been lost during the experiment, the metal at the same time returning to its original state and weight; while the air, thus separated, if added to the residual portion, not only restores the volume and weight of the original quantity; but also its power of supporting life and flame.

If, instead of a metal, certain inflammable substances be employed, similar changes are effected on the air; and the inflammable substance, together with an increase of weight and other alterations, acquires acid properties; and hence that respirable portion of the air has, from a Greek derivation, been called *oxygen;* as being the effective cause of the acidification of those inflammable bodies. It has moreover been ascertained that, during combustion, a piece of pure charcoal weighing twenty-eight grains combines with as much oxygen gas as would weigh seventy-two grains: and, as the volume of the gas employed remains the same at the end of the experiment that it was at the beginning provided it be brought to the same degree of temperature and atmospherical pressure, it appears that the carbon is as it were held in solution by the gas: and as this chemical compound of carbon and oxygen possesses acid properties it is called *carbonic acid gas.*

A volume of this gas, then, which weighs one hundred grains, consists of twenty-eight grains of carbon chemically combined with seventy-two grains of oxygen: and it has certain properties, by which, without the labour of actual analysis, it may be recognised from any other gas; among the more important of which, for our present purpose at least, is the readiness with which it communicates a wheyish appearance to lime-water, when made to pass through that liquid. Making use of this character as a test, any individual may easily satisfy himself that during the process of respiration a quantity of carbonic acid gas passes from his lungs: for if, after having inhaled a portion of atmospherical air uncontaminated with any mixture of it, he breathe slowly through a narrow tube, the further extremity of which is immersed beneath the surface of a portion of lime-water, he will observe that as the bubbles of air rise through the lime-water, that liquid becomes opaque; and the opacity thus communicated to the water can be shown to be the result of a compound formed by the union of the carbonic acid, which has evidently been given out from the lungs, with the lime previously held in solution in the lime-water.

Let it now be kept in mind that a hundred cubic inches of carbonic acid gas, under ordinary circumstances, weigh a little more than forty-six grains; and that a quantity of the same gas weighing

a hundred grains contains twenty-eight grains of carbon; and the following statement will be easily intelligible. It appears, from experiments which have been made for the purpose, that during the process of respiration in an individual of ordinary size and health, about twenty-seven cubic inches and a half of carbonic acid gas are given off from the lungs in the course of one minute; which at the end of twenty-four hours would amount to 39,600 cubic inches, or in round numbers 40,000; and as 100 cubic inches weigh 46⅓ grains, 40,000 would weigh 18,532 grains. Then since a quantity of carbonic acid gas weighing 100 grains contains twenty-eight grains of carbon, a quantity weighing 18,532 grains would contain 5190 grains, or nearly eleven ounces, at 480 grains to an ounce: so that a quantity of carbon equalling two thirds of a pound in weight is daily discharged from the blood by means of the simple process of respiration.

In an illustration of the general question of the adaptation of external nature to the physical condition of man, it is clearly immaterial whether, during the process of respiration, the carbonic acid is supposed to be produced by the union of the carbon of the animal system with the oxygen of the air respired; or whether, as is possible, the carbonic acid, having been previously formed in the body at large, is given off in the form of carbonic acid gas from the lungs, while the oxygen gas of the atmosphere is absorbed by those organs. The main point to be considered is, the fact of the removal of that quantity of carbon, which could not be retained with safety to the life of the individual: and when we consider that the entire quantity of the carbon, thus discharged, is collected from every the most interior and remote part of the body, how worthy of admiration is the economy of nature in producing the intended effect! The air is the medium through which the carbon is to be discharged; and yet the constitution of the body is such, that the air could scarcely be introduced into any of its internal parts without occasioning the most serious consequences, if not death itself: but by means of the circulation of the blood, that beautiful contrivance intended primarily for sustaining the nourishment and warmth and life of every part, the noxious principle is conveyed to the lungs: where it is of necessity brought, if not actually, yet virtually, into contact with the air; and thus it is effectually removed from the system.

Section IX.

Effects of the Motion of the Air, as connected with Human Health, &c.

In the history of water we had an opportunity of observing how extensive are the benefits arising to mankind from that physical

property, by which its particles are capable of moving with the greatest ease among each other: nor are the benefits less considerable, which arise from the same property in the element now under consideration; especially when aided by those alterations in its volume, which follow upon every change of temperature: for from these combined causes arise those currents of air, which administer, in various modes, as well to the luxury and comforts of man, as to his most important wants.

Who does not see the miseries that would result from a stagnant atmosphere? To the houseless and half-clothed mendicant indeed, who under exposure to a wintry sky instinctively collects his limbs into an attitude as fixed as marble, lest by their motion he should dissipate the stratum of warmer air immediately surrounding his body—to such an individual indeed, under such circumstances, a stagnant atmosphere becomes a benefit of the highest value; not only by preventing or moderating the painful sensation of cold; but by preventing the dissipation of that degree of heat which is necessary for the preservation of the vital principle, which in his unsheltered state might otherwise possibly be soon extinguished. But let circumstances be reversed; and, instead of the wretched beggar exposed to an inclement sky, let us picture to ourselves an Asiatic prince surrounded by all the luxuries which power and opulence can procure, but oppressed by the sultry atmosphere of a burning sun; how grateful to his feelings is the refreshing coolness occasioned by the artificial agitation of the surrounding air: in order to extend the means of obtaining which gratification, fountains of water are customarily introduced into the interior rooms of Indian and Arabian palaces, the evaporation of the spray of which gives a refreshing coolness to the air. Or let us recur to scenes more familiar, and more illustrative of the effect produced; to the bedside of the almost exhausted invalid, whose existence is alone made tolerable by the assiduous supply of fresh streams of air: there let us witness, in the thankful smile which animates his pallid countenance, the soothing sensation which the languid sufferer experiences. Even for such a momentary solace, what, of all his most valuable possessions, would not every one of those miserable victims have surrendered, who once perished in that dreadful dungeon of Calcutta?

In many instances nature tempers the high degree of heat belonging to particular climates, by the periodical recurrence of cooling winds at stated hours of the day. Thus, in the islands and on the coasts in general of the tropical regions of the earth, the alternations of what are called the sea and the land breeze are of the highest importance to the comfort and health of the inhabitants: of which the following statement, taken from an official paper on the medical topography of Malacca, furnishes a sufficient illustration.*

* Printed at the government press, Pinang, 1830. See the Edin. Med. and Surg. Journal, for July 1831, p. 179

"The Malay peninsula possesses, though within the tropics, and almost under the equator, a very equable temperature and mild climate. Whatever be the prevailing wind, the sea-breeze generally sets in from the south between ten and twelve in the morning, and continues till six or seven in the evening; when, after a short calm, the land wind begins to blow from the north-east: and so constant are these breezes, that, unless during a storm, the influence of the monsoon is scarcely perceptible. And so uniform is their effect, with respect to the temperature of the air, that, throughout the year, the variation does not exceed fourteen or fifteen degrees of Fahrenheit: being rarely higher than eighty-eight degrees, or lower than seventy-four degrees."

And though the hurricanes, to which these regions are frequently exposed, are occasionally most dreadful in their effects upon the property and even the lives of the inhabitants; yet we may not only be assured on general principles of reasoning that in the main they are beneficial, but on some occasions we have immediate demonstration of their remedying a greater evil. Thus when swarms of a peculiar species of ant had, during many years, ravaged the island of Grenada, to so serious an extent that a reward of twenty thousand pounds had been offered to any one who should discover a practicable method of destroying them; and when neither poison nor fire had effected more than a partial and temporary destruction of them, they were at once swept away by a hurricane and its accompanying torrents of rain. Of the numbers in which these insects occurred, some estimate may be formed from the following statement of an eyewitness of credible authority; who says "he had seen the roads coloured by them for many miles together; and so crowded were they in many places, that the print of the horse's feet was in a moment filled up by the surrounding swarms."*

We who rarely are oppressed, for more than a few hours in a whole summer, by such a state of the atmosphere as occasionally precedes a thunderstorm, when no friendly breeze interposes to remove the close and humid stratum of air which envelopes our bodies, may well be thankful that our lot has not been cast in certain regions of the earth; in those Alpine valleys, for instance, whose scarcely human inhabitants attest the dreadful consequences of a confined atmosphere: the influence of which often affects not only the present sensations and comforts, but even the intellectual, and eventually the moral character, of those who are habitually exposed to it.

It appears, from recent inquiries, that the physical and intellectual and moral degradation, so often observable in the inhabitants of mountain valleys in general, but noticed particularly in the valleys of the Rhone, may be referred with probability, among other causes,

* Philos. Trans. 1790, p. 347.

to a stagnant atmosphere; and to the reverberation of heat from the sides of the mountains which bound those valleys, co-operating with an alternation of piercing winds: the degree of that degradation at least is always proportional to the action of those causes.

It is not necessary here to dwell minutely on the disgusting alteration which the human beings, now particularized, undergo: those who are desirous of such information may consult a very recent work by Dr. James Johnson.* All that is here intended is a statement of the general fact. And it appears that, in the milder instances, the principal alteration which takes place is an enlargement of the thyreoid gland; which enlargement is by medical men called *bronchocele*, and by the inhabitants of the Alps *goitre*.† In the instances of extreme alteration, the stature rarely reaches the height of five feet; the skin becomes unnaturally discoloured, and disfigured by eruptions; the limbs distorted; and the *cretin*, for so he is denominated in this state, is frequently, in addition, both deaf and dumb, and entirely idiotic. Between the state of simple goitre and that of most perfect cretinism the degree of alterations are innumerable. And, as indicating the connexion between this unnatural state of the individual, and the atmosphere which he habitually respires, the following observation is worthy of attention. "In the Vallais," and "in the lower gorges or ravines that open on its sides, both cretinism and goitre prevail in the most intense degrees: as we ascend the neighbouring mountains, cretinism disappears, and goitre only is observed; and when we reach a certain altitude, both maladies vanish."‡

Among the physical effects of the motion of the air, that of sound is among the most remarkable and important: of the intimate nature of which, however, and of the laws that regulate its transmission, I should not speak more particularly, even if I felt myself competent to the task; being a subject of too abstruse a character in itself to claim a close investigation in a treatise like the present: besides which, it will be examined in a separate treatise by others. Whatever may be the moral effects either of simple sounds, or of certain combinations of sounds, and such effects though apparently of a fugitive character are occasionally very powerful, there can be no doubt that particular sounds act physically on our frame. Thus the gentle murmur of running water, or the repetition of any simple tone, even though not agreeable in itself, is calculated to soothe the whole nervous system so as to induce sleep. There are few perhaps who have not experienced such an effect, from long continued atten-

* Change of Air, &c. by James Johnson, M. D. London, 8vo. 1831.

† Such an enlargement we often in this country witness in individuals, who, in every other respect, are so far from being deformed, that they are frequently remarkable both on account of their beauty, and the symmetry and full developement of their whole body.

‡ Change of Air, &c. p. 58.

tion a to public speaker; and an apparent, though probably not the legitimate, proof of the effect having been produced by the sound of the voice of the speaker is derived from the fact, that upon his ceasing to speak, the sleeper usually awakes. There are few, again, who have not known from personal experience that certain tones affect the teeth with that peculiar and unpleasant sensation familiarly described under the term, *set on edge*. Even in the appalling sensation excited by thunder, the mind is probably overawed by the physical effect produced on the nervous system by the crash, rather than by any apprehension of danger from the thunder itself: for that sensation is usually excited even in those who are most assured that no danger is to be expected from the loudest crash of the thunder, but only from the lightning which accompanies it. Nor is it unreasonable to suppose that an analogy exists between the sense of hearing and the other senses, with reference to the objects of their several sensations: and since in the case of taste, of sight, of smell, and of touch, some objects are on reasonable grounds conjectured to be naturally offensive, while others are agreeable to the respective senses; why, it may be asked, should not the same relations hold with respect to the ear and the peculiar objects of its sensation? Evelyn well observes, that the bountiful Creator has left none of the senses which he has not gratified at once with their most agreeable and proper objects.

Of all the objects of sense, sound perhaps, as a principle of mental association, the most powerfully excites the recollection of past scenes and feelings. Shakspeare briefly elucidates this principle in these lines:

> " Yet the first bringer of unwelcome news
> Hath but a losing office ; and his tongue
> Sounds ever after as a sullen bell,
> Remembered knolling a departed friend."
>
> HENRY IV. Part II. Act I. Scene 1.

The author of the "Pleasure of Memory" not less forcibly illustrates the same principle.

> "The intrepid Swiss, who guards a foreign shore,
> Condemned to climb his mountain cliffs no more,
> If chance he hear the song so sweetly wild,
> Which on those cliffs his infant hours beguiled,
> Melts at the long-lost scenes that round him rise,
> And sinks a martyr to repentant sighs."
>
> ROGERS, &c. page 21, line 1.

Nor is the principle less powerfully illustrated in that most beautiful Psalm beginning with the words, "By the waters of Babylon we sat down and wept:" for who can read that affecting apostrophe, " How shall we sing the Lord's song in a strange land," without entering into all the pathos of the scene represented by the sacred poet to the imagination?

It is said to be the opinion of the Hindoos, and though not of much value in argument, there is at least a metaphysical elegance in the opinion, that the remarkable effects of music on the human mind depend on its power of recalling to the memory the airs of paradise, heard in a state of pre-existence.

But, if an individual instance of the truth of the present position were to be selected, it would not be possible perhaps to find one more impressive than that which has been recorded of the late emperor of the French. It is said that at that period of his life, when the consequences of his infatuated conduct had fully developed themselves in unforeseen reverses, Napoleon, driven to the necessity of defending himself within his own kingdom with the shattered remnant of his army, had taken up a position at Brienne, the very spot where he had received the rudiments of his early education; when, unexpectedly, and while he was anxiously employed in a practical application of those military principles which first exercised the energies of his young mind in the college of Brienne, his attention was arrested by the sound of the church clock. The pomp of his imperial court, and even the glories of Marengo and of Austerlitz, faded for a moment from his regard, and almost from his recollection. Fixed for a while to the spot on which he stood, in motionless attention to the well known sound, he at length gave utterance to his feelings; and condemned the tenour of his whole subsequent life, by confessing that the hours, then brought back to his recollection, were happier than any he had experienced throughout the whole course of his tempestuous career. He might perhaps with truth have added, when looking at the various objects of the surrounding scenery,

> "I feel the gales, that from ye blow,
> A momentary bliss bestow."

Perhaps also during this moment, and in making a confession so humiliating, he actually did experience that moral state represented by Milton to have been felt by the fallen angel—

> "Thrice he essayed (to speak); and thrice, in spite of scorn,
> "Tears, such as angels weep, burst forth—"

But the effect produced on his mind seems to have been momentary; at least it certainly did not alter his course of action. And too probably he was at that time rather tormented by remorse, than softened by repentance; a state but little favourable to the adoption of better counsels, even if he could then have retrieved his fortunes by such a change.

Section X.

Effects of the Motion of the Air, as connected with the Arts, &c.

I proceed now to consider the effects of the atmosphere, while in a state of motion, in aiding the various arts and operations of civilized

society; in which the action is sometimes explicable on mechanical, sometimes on chemical, or on physical, principles.

It would not be a short or easy task to enumerate the various substances which require to be deprived of all sensible moisture, in order to be applicable to the immediate purposes of life; nor in order to be capable of being preserved in a state fit for future use: and the separation of that moisture which they may contain in their natural state, or which they may have accidentally contracted, can in general only be effected by exposure to the open air: but as that portion of the air, which is in contact with the moistened substance, would soon be so far saturated with the vapour arising from it as to be incapable of absorbing more, it must necessarily be replaced by successive portions of fresh air; in order that the substance may be thoroughly dried: and hence we see the advantage of currents of air, or, in common language, of the wind, for the purposes in question. Without the aid of such currents, the grass newly mown would often with difficulty be converted into hay: and with still more difficulty would that conversion take place should it during the process, as is most likely to happen, be exposed to rain. The same difficulty would occur, but attended with much more serious effects, in the case of sheaves of wheat or barley, which having been once drenched with rain would be rendered unfit for producing bread, unless the moisture were soon dissipated: and with respect to the process of reducing the corn itself to the state of meal, that is, in common language, of grinding it; although many other mechanical means are capable of being applied to that purpose, who does not see the advantages of the common windmill, even where other means are available, which in many places they would not be? but windmills would themselves be unavailable, were there no currents of air to set them in motion.

In the drying of moistened linen, and of paper newly made; in the seasoning, as it is called, of wood; and on numerous other occasions, the same advantages occur from the same cause, and are explicable in the same way. But there is one instance, of very familiar occurrence, where the effect of a free ventilation is productive of the greatest comfort. At the breaking up of a long protracted frost, during which the air has been enabled to absorb and retain in an insensible state an unusual quantity of moisture, that moisture, as soon as the thaw takes place, is deposited upon the surface of every thing with which it comes in contact: and there can be scarcely an individual, from the peasant to the noble, who has not often experienced the comfortless state of the interior of his habitation from this cause. The opulent indeed, supposing that nature did not provide the remedy, might easily remove, and often do accelerate the removal of the evil, by the introduction of currents of air artificially heated: but the indigent, incapable of commanding so expensive a remedy, would meet with serious detriment, did not a timely change in the state of the atmosphere enable it to re-absorb the moisture which had pre-

viously been discharged from it; for many parts of the furniture of their habitation would be injured, or even destroyed by the moisture imbibed by them: and with respect to a much more important point, a healthy state of body, both the opulent and the indigent would be alike sufferers, from a continued exposure to the external atmosphere in such a state.

In the foregoing instances currents of air have been considered as acting on a fixed point as it were, or on bodies nearly stationary. Let us now consider their action on bodies capable of being set in motion, as nautical vessels of all kinds, and we shall not fail to see the importance of that action to some of the highest interests of man.

To those, of whatever condition in life, who are surrounded by the numerous resources of a commercial city, it is immediately of little import, unless as a question of mere corporeal feeling, whether the air be in a state of perfect calm, or freshened by a breeze; and whether that breeze be from the east, or from the west. To the agriculturist even it is comparatively of little interest, unless at particular seasons, whether the wind be high or low, or from what quarter it may come; further than as particular states and directions of the wind are indications of rain or drought. But to those "who go down to the sea in ships, and occupy their business in great waters," not only the degree of force, but the direction of the wind, is of the highest moment: while on many occasions, even in the present advanced state of science and naval architecture, a motionless state of the atmosphere, or a calm, might be fatal to all their speculations. Every one who has lived for a time on the sea-coast must have observed with what anxiety the owner of the smallest fishing boat watches the variations in the state or direction of the wind, as connected with the practicability of putting out to sea. If the wind be in an unfavourable quarter, or if it blow not with sufficient force to swell his sails, he saunters in listless inactivity along the beach: but if the wished for breeze spring up, the scene is at one changed, and all is alacrity and life.

In some parts of the world Providence has compensated for the disadvantages arising from the general uncertainty of the wind, by the continued regularity of its direction through stated seasons: in consequence of which, the merchantman calculates upon the commencement and duration of his voyage with a degree of security and confidence, which sets him comparatively at ease as to the event. These periodical currents of air indeed have been named from this very circumstance the *trade winds:* and, in illustration of their adaptation to the purposes of commerce, a more striking instance perhaps could not be adduced than the following, which is given in a volume, entitled, "Four Years Residence in the West Indies," written by a gentleman by the name of Bayley.* In the description of the island

* London, 8vo, 1830, p. 292.

of St. Vincent it is there stated that a little sloop, the private signal of which was unknown to any of the merchants, sailed into the harbour one morning, and immediately attracted the notice of the surrounding crowd; and the history of its unexpected appearance is thus given. "Every one has heard of the little fishing smacks employed in cruising along the coast of Scotland; which carry herrings and other fish to Leith, Edinburgh, or Glasgow, worked by three or four hardy sailors, and generally commanded by an individual having no other knowledge of navigation than that which enables him to keep his dead reckoning, and to take the sun with his quadrant at noonday.

"It appears that a man who owned and commanded one of these coasting vessels had been in the habit of seeing the West India ships load and unload in the several ports of Scotland; and, having learned that sugar was a very profitable cargo, he determined, by way of speculation, on making a trip to St. Vincent, and returning to the Scottish market with a few hogsheads of that commodity. The natives were perfectly astonished—they had never heard of such a feat before; and they deemed it quite impossible that a mere fishing smack, worked by only four men, and commanded by an ignorant master, should plough the boisterous billows of the Atlantic, and reach the West Indies in safety; yet so it was. The hardy Scotchman freighted his vessel; made sail; crossed the bay of Biscay in a gale; got into the *trades;* and scudded along before the wind, at the rate of seven knots an hour, trusting to his dead reckoning all the way. He spoke no vessel during the whole voyage, and never once saw land until the morning of the thirty-fifth day; when he descried St. Vincent's right a-head: and setting his gaft-topsail, he ran down under a light breeze, along the windward coast of the island; and came to anchor about eleven o'clock under the circumstances before mentioned."

Such a vessel, and so manned, could hardly have performed the voyage here described, had it not been aided by the current of the trade wind: and what then must be the advantage of such a wind, when, instead of aiding the puny enterprise of a single and obscure individual, it forwards the annual fleets of mighty nations. Most important therefore to the Roman empire was the discovery of Hippalus, which enabled its fleets to stretch across at once from the African to the Indian coast by means of the south-westerly monsoons. But, if we would view the subject in all its magnitude, let us contemplate with a philosophic eye the haven of any one of the larger sea-ports of Europe; filled with vessels from every maritime nation of the world, freighted not only with everything which the natural wants of man demand, or which the state of society has rendered necessary to his comfort, but with all which the most refined luxury has been able to suggest. "Merchandise," to use the words of Scripture, "of gold, and silver, and precious stones, and

of pearls, and fine linen, and purple, and silk, and scarlet, and all thyine wood, and all manner vessels of ivory, and all manner vessels of most precious wood, and of brass, and iron, and marble, and cinnamon, and odours, and ointments, and frankincense, and wine, and oil, and fine flour, and wheat, and beasts, and sheep, and horses, and chariots."

But the importance of all the foregoing points of consideration in the history of the relation of the air to human wants is far inferior to that highest and most beneficial of all its relations, the production of the human voice: for from this source arises articulate language; without which medium of communication between man and man, what would become of the most important transactions of the business of life, as well as of its most rational pleasures, the charms of social converse? But the consideration of the mechanism of the human voice is appropriated to a distinct treatise: and the use of language is adapted rather to the moral than to the physical condition of man: and I therefore forbear to dwell on a theme in itself of the highest interest.

In dismissing the subject of atmospherical air, I would wish to observe how beautiful an instance its history affords of the multiplicity of beneficial effects, of very different characters, produced by one and the same agent; and often at one and the same moment. Thus while we have seen the air of the atmosphere serving as the reservoir of that mass of water from whence clouds of rain, and consequently springs and rivers are derived, we have also seen that it at the same time prevents, by the effect of its pressure on their surface, the unlimited evaporation and consequent exhaustion of the ocean, and other sources, from whence that mass of water is supplied. And, again, while the agitation of the air contributes to the health of man, by supplying those currents which remove or prevent the accumulation of local impurities, it at the same time facilitates that intercourse between different nations in which the welfare of the whole world is ultimately concerned. And lastly, while in passing from the lungs in the act of expiration it essentially forms the voice, it at the same time removes from the system that noxious principle, the retention of which would be incompatible with life.

CHAPTER VII.

ADAPTATION OF MINERALS TO THE PHYSICAL CONDITION OF MAN.

Section I.

The general Characters of Minerals.

It has been shown in the foregoing chapter, that the constituent parts of the atmosphere are few in number, and of great simplicity in their composition; that some of them usually exist in the state of invisible vapour, and consequently are without sensible form and colour: and that others, as light, and heat, and electricity, are not only without form and colour, but are also of such tenuity as to be incapable of affecting the most delicately constructed balance; in common language, are without weight. We are now entering on a department of nature, which consists of objects characterised by properties very different from those we have been lately considering; remarkable, as a class, for the mathematical precision of their form, the brilliancy and variety of their colour, and for their great weight; most of them being many times heavier than the heaviest element of the atmosphere.

Few mineral substances, however, exist in such a state of purity as to exhibit the simple characters of their individual properties; the class consisting of a great variety of species, which are capable of entering into union with each other, and of which the natural combinations are extremely numerous. But, as might be anticipated from the general analogy of nature, the advantages arising to mankind from this mixture of character are infinitely greater than if the individual minerals had existed in a state of purity, and uncombined with each other. Thus, to take the most familiar, and perhaps the most important instance, almost all natural soils consist principally of mixtures of the three earths called *silex*, *lime*, and *alumine;* none of which, unmixed with either of the other two, or at least, with some equivalent substance, would serve the purposes of agriculture.

Again, all the common forms of clay consist principally of various combinations of the two earths called *silex* and *alumine;* and although many of those properties which make clay valuable are communicated by the alumine, the silex contributes very considerably towards the general utility of the compound.

Section II.

Application of Minerals to Architecture and Sculpture.

Among the earliest arts of civilized life may be justly reckoned the rudiments of architecture: for it may be with truth affirmed that, with very few exceptions, wherever man exists in a state of society, he is found to protect himself from the vicissitudes of the weather, not only by the immediate clothing of his body, but by means of independent habitations; to which, if at no other time, at the close of the day at least, he betakes himself; in order to enjoy that periodical rest which is requisite for the renewed exertion of his bodily powers: and very few are the situations which do not afford convenient materials for the purposes of building.

In whatever situation then man may be placed, he will most probably have the means of procuring the comfort of a fixed habitation. Nor is it long before he adds a certain degree of luxury to utility: for wherever the simple architecture of the dwelling is not decorated with some ornamental additions, we may be certain that society exists in a very low state of civilization; so that sculpture, as an artificial refinement, seems to be a natural consequence of architecture. And, perhaps, the superiority attainable by education and habit is not displayed in any of the arts of life so strikingly as in these. From the simple tent of the Bedouin to the majestic ruins of Palmyra, among which it is pitched; or from the rude hut of the modern Acropolis to the awful grandeur of the Parthenon which overshadows it; how infinite are the gradations which mark the progress of these arts!

And with respect to statuary, that highest department of the art of sculpture, what emotions is it not capable of raising in the mind, particularly when employed in representing the passions or any of the attributes of man! If, for instance, the mind of the savage could be instantaneously elevated to the feeling of correct taste, what would be the sensations of the islander of the southern Pacific, in turning from the view of his hideously-formed and grim idol, to the contemplation of that glory of the Vatican,

> ———"The Lord of the unerring bow,
> The God of life, and poesy and light;
> The sun in human limbs arrayed, and brow
> All-radiant from his triumph in the fight:
> ——— in whose eye
> And nostril, beautiful disdain, and might,
> And majesty, flash their full lightnings by,
> Developing in that one glance the Deity."*

* Childe Harold, canto IV. stanza 161.

I will not here attempt to trace the history of architecture, considered as an art characteristic of civilized society: for in such an attempt our reasoning must often be founded on conjecture instead of facts; than which nothing is more unsatisfactory and irksome to a philosophically contemplative mind. It will be more congenial to the purpose of this treatise to point out the means afforded by nature for the advancement of an art, which in its origin is necessary to some of the chief wants and comforts of individuals; and which is subsequently conducive, by the exercise of the highest faculties of the mind, not only to national utility and glory, but also to national security.*

With respect to the inferior animals, the instinctive propensity to construct receptacles for themselves or their offspring is obvious: and if on any ground we may attribute the principle of instinct to man, it seems justifiable on that which we are now considering. Omitting, however, those more remarkable instances of instinct which direct the bee, the ant, the spider, the swallow, or the beaver, in the fabrication of the structures which they put together with such nice art; if we merely consider the simple burrow of the rabbit or the mole, we seem to acquire a strong presumption, that man would not be destitute of a similar instinct: and it may reasonably be supposed that, by whatever intellectual power or internal sensation the savage is directed so to adjust the various joints and muscles of his limbs as to balance his body when in danger of falling, by a similar power he is enabled so to adjust the rude boughs of which his hut is composed, that by mutually supporting one another they may at the same time serve for a support to the grass, or moss, which is thrown over them for the purpose of forming a shelter.† Numerous traces of such an instinct are observable in the

* In the construction for instance of military fortifications, and piers, and bridges, &c.

† The following statement, from Lewis and Clarke's Travels, will show how much may be effected by human ingenuity and industry though aided by the slightest means: "The Columbian Indians possess very few axes; and the only tool employed in their building, from the felling of the tree to the delicate workmanship of the images, (adorning their canoes,) is a chisel made of an old file: and this is worked without the aid of a mallet. But with this, they finish a canoe fifty feet long, and capable of holding between twenty and thirty persons, in a few weeks." p. 435. To the preceding statement may with propriety be added the following translation of the account which accompanies the twelfth plate in the first volume of De Bry: "The method of making boats in Virginia is truly wonderful: for, although the natives have no instruments of iron, or in any way resembling those of European nations, they still have the power of making boats fully capable of being conveniently navigated. Having selected a large and lofty tree, they surround it with a fire just above the roots; taking care to smother any flame, lest it should injure the rising part of the stem. In this way they burn through the greater part of the stem; and, by thus weakening it, occasion its downfall. By a similar process they burn away the branches and the upper part of the tree; and, raising the trunk thus prepared on forked props, so as to support it at a convenient height for working, they scrape away the bark by means of large shells; and then excavate it in a longitudinal direction by alternately burning and scraping it."

amusements of children; as in the arrangement of loose stones in the form of enclosures; and in the formation of banks and dikes by the heaping up of the sand of the sea-beach: and, should it be asserted that such amusements are not to be referred to instinct, but are to be classed simply under the principle of imitation, (as may certainly many of the amusements of children,) it may be answered, that, if not original instincts, they may be considered as at least instinctive imitations of the necessary engagements of after-life. It has been sometimes supposed that the inclining branches of an avenue of elms or other trees suggested the idea of the gothic aisle; but such a supposition seems both unnecessary in itself, and incorrect as to the probable order of occurrences: for whoever has read the travels of Pallas through different parts of the Russian empire, or of other Oriental travellers, will find ample proof of the existence of the gothic style of architecture long before our earliest European churches were built: and it is just as probable, if not more so, that the gothic aisle suggested the idea of the elm avenue, as that this suggested the idea of the gothic aisle.

The mineral substances employed in the structure of human habitations necessarily differ in different parts of the world, in consequence of the difference of the materials afforded by the subjacent strata; and, accordingly, an experienced eye will conjecture, almost with certainty, the character of the subjacent strata, from the nature of the materials employed in the buildings erected on the surface: or, conversely, if the nature of the subjacent strata be antecedently known, the character of the stone employed in the buildings of the vicinity will, almost to a certainty, be known also; and, on this principle, as much surprise would be excited in the mind of a well-informed geologist by the prevalence of granite in the buildings of Kent or Sussex, as of limestone near the Land's End in Cornwall.

The nature, however, of the material employed in building is in some measure determined by the particular stage of civilization of the inhabitants. Thus in the early periods of civilization, and before the aboriginal forests of a country have been cleared, wood has usually been the principal and almost the only substance employed. In proportion as the population of a country increases, wood becomes more and more scarce; and then brick and stone begin to be employed: but when the population has increased to a very considerable extent, those materials almost entirely supersede the use of wood, unless in the interior of the building: and hence, in this densely-peopled island, the half-timbered dwellings of our ancestors are daily becoming more picturesque*

The value of building-stone depending greatly on its hardness, but

* Throughout the interior of Russia and of Siberia the greater part of the buildings in every town were, within a few years, entirely of wood.

the difficulty of working it being increased proportionally to its degree of hardness, it ought not to escape our notice, in a treatise, of which it is the professed object to illustrate the adaptation of external nature to the physical condition of man, that many of the common forms of building-stone, though soft while yet undetached from the quarry, become hardened very considerably by exposure to the air: which change in their state enhances their value in a twofold sense; for, in consequence of their previous softness, they are more easily worked; while their subsequent hardness insures the greater durability of the building in which they are employed. And, again, though many varieties of stone are so easily worked, even after a long exposure to the air, as to have acquired in consequence the name of *freestone;* yet even with respect to such as are of the hardest and toughest quality, an equal degree of ease in working them is easily attainable by practice. To an unpractised workman, for instance, nothing is more difficult than to give a determinate form, by the hammer or chisel, to granite, slate, or flint; and yet a little experience enables the mason to work all these to the greatest nicety: and that person would indeed be very incurious, who, although he might not naturally be disposed to notice mechanical processes, did not feel an interest in observing the form which the roofing-slate takes under the bill of the slater; or the ease with which the gunflint is formed into its peculiar shape by a few strokes of a light hammer.

But, after the stones have been detached from the quarry, and have been worked into a convenient form for building, it is in the greater number of instances necessary to the stability of the intended structure, that they should be consolidated together by some intermediate substance: for it would very rarely happen that the separate stones could be obtained of such a size as to be capable of remaining fixed by their own weight. Sometimes this effect is produced by means merely mechanical, as in the case of the construction of the larger circle of Stonehenge; where the upper extremity of two contiguous perpendicular stones, being pared away so as to form what is called a *tenon*, is let into a corresponding cavity called a *mortise* cut into each extremity of the horizontal stone that unites them.

As such Cyclopean masonry would be far too expensive for common purposes; and as the labour and expense of uniting together, by cramps of iron or other mechanical means, the very great number of stones requisite for the construction of even a small building, would be endless; we at once see the importance of any medium that will fully and readily effect that union, without much expense of time or money: and how completely the substance called *mortar* answers the intended purpose, the slightest observation will make manifest. As the employment of this useful substance appears to have existed antecedently to history, it is not worth while to spend

any time in conjecturing how it was first discovered: but it is quite in unison with the intention of the present treatise to observe, that, of the three materials of which it is principally made, namely lime, sand, and water, the first is readily obtained by the simple application of heat to any common form of limestone, a process which is occasionally going on in every limekiln; and the means of obtaining the two others are almost every where at hand.

Hitherto the materials, applicable to the arts of architecture and sculpture, have been considered as adapted to the common or necessary wants of mankind: but in what may not improperly be called the poetry of those arts, they are capable, in their application, of eliciting the highest powers of the imagination: for surely this may with propriety be affirmed of such sublime productions as the Parthenon in architecture, or the Belvedere Apollo in sculpture. Nor are we obliged to seek for such productions solely in the classic ages of antiquity: for, to say nothing of Palladio, Michael Angelo, Canova, Thorvaldson, and other ornaments of modern Europe, our own country has given birth to works of the highest excellence in either department of the art. Nor need this assertion be made with any hesitation, while in architecture that imperishable monument of genius, the Eddystone lighthouse, attests the fame of Smeaton; and in sculpture, the pure and simple taste of Chantrey has, in that most exquisite work contained within the walls of Litchfield cathedral, thrown a truth and beauty over the image of death, which none of his predecessors had ever attained.*

Who can peruse the journal of Smeaton, and not admire the penetration, the resources, and the activity of his genius? Consider the nature of the task which he had engaged to perform; his limited and uncertain opportunities of action; the failures of others who had preceded him in a similar undertaking; the consequent necessity of new principles, and new combinations, in his plan of operations; the formidable dangers he was continually under the necessity of encountering; and, lastly, the awful responsibility of the undertaking itself: consider all these points, and it may be safely affirmed that, as an instance of the conjoined effects of personal enterprise, fortitude, and perseverance, the Eddystone lighthouse stands unrivalled.

On a small, precipitous, and completely insulated rock, deriving its very name from the irregular and impetuous eddies which prevail around it; elevated but a few feet above the level of the surrounding ocean, even in its calmest state; and exposed at all times to the uninterrupted swell of the Atlantic; by the joint violence of the wind and waves of which, a preceding structure had been in a moment swept away, leaving not a wreck behind; on such a spot was this new wonder of the world to be erected. Former experi-

* One exception to this assertion perhaps exists, in a work on a similar subject by Banks; in the church of Ashbourne, Derbyshire.

ence is here of little avail, and common principles and means have been already tried in vain; the architect is thrown almost entirely on his own resources; and they do not fail him. In order to combat the force of those overpowering elements to which the future structure is to be constantly exposed, he looks about for that *natural* form which is found most permanently to resist a similar conflict; and viewing with a philosophic eye the expanded base of the oak, and the varying proportions of its rising stem, he made the happy selection of this object as the type of the proportions of his intended work.

"On this occasion," he himself says,* "the natural figure of the waist or bole of a large spreading oak presented itself to my imagination. Let us for a moment consider this tree: suppose at twelve or fifteen feet above its base, it branches out in every direction, and forms a large bushy top, as we often observe. This top, when full of leaves, is subject to a very great impulse from the agitation of violent winds; yet partly by its elasticity, and partly by the natural strength arising from its figure, it resists them all, even for ages, till the gradual decay of the material diminishes the coherence of the parts, and they suffer piecemeal by the violence of the storm: but it is very rare that we hear of such a tree being torn up by the roots. Let us now consider its particular figure—connected with its roots, which lie hid below ground, it rises from the surface thereof with a large swelling base, which at the height of one diameter is generally reduced by an elegant curve, concave to the eye, to a diameter less by at least one third, and sometimes to half of its original base. From thence its taper diminishing more slow, its sides by degrees come into a perpendicular, and for some height form a cylinder.

"After that, a preparation of more circumference becomes necessary for the strong insertion and establishment of the principal boughs, which produces a swelling of its diameter. Now we can hardly doubt but that every section of the tree is nearly of an equal strength in proportion to what it has to resist: and were we to lop off its principal boughs, and expose it in that state to a rapid current of water, we should find it as much capable of resisting the action of the heavier fluid, when divested of the greatest part of its clothing, as it was that of the lighter when all its spreading ornaments were exposed to the fury of the winds: and hence we may derive an idea of what the *shape* of a column of the greatest stability ought to be, to resist the action of external violence, when the *quantity* of matter is given whereof it is to be composed."

But invention and composition, do not constitute the whole of the character of genius, in the practical arts at least. Industry, both

* A Narration of the Building, &c. of the Eddystone Light-house, London, 1791, p. 42.

that which resists the listlessness arising from continuity and sameness of pursuit; and, still more, that which, though repeatedly repressed by unexpected impediments, as repeatedly recovers its elasticity; unconquerable and indefatigable industry, like that of the ant, is likewise requisite. And such industry did Smeaton manifest: and his industry has hitherto been completely crowned with success. The Eddystone has withstood the war of winds and waves through the greater part of a century, unshaken in a single point: and if of any human work we dare affirm as much, we might affirm of this, "manet æternumque manebit."

We now turn to the efforts of genius, of another, and, intrinsically, a higher order—to that beautiful composition of Chantrey, to which allusion has been already made. A different task is here to be accomplished: it is not the storm of the physical elements which is to be resisted, but the poignant grief of the bereaved parent is to be assuaged; and that, not by any *nepenthe* which may obliterate the memory of lost happiness; but by, I had almost said, the living image of the very objects themselves from which that happiness arose, and in which it centred. Alone, and undistracted by the presence of surrounding friends, the widowed mother approaches in mournful silence the consecrated aisle; where, softly clasped in each other's arms, she sees her beloved children resting in the repose of sleep rather than of death: and gazing on them with intense affection, she feels not sorrow for a while; but, indulging in a dream which almost realizes her past happiness, would fold her treasures to her bosom, were she not too conscious that the cold embrace would dissipate the fond illusion.

Section III.

Gems and Precious Stones.

If it were the purpose of this treatise to point out the adaptation of external nature to the moral as well as to the physical condition of man, it might be easily shown, that, however an undue degree of attention to outward ornaments is blameable, a moderate degree of attention is both allowable and right: otherwise, and it is an instance that outweighs all others, it would not have been observed in the decorations of the temple of Solomon, nor in the original ordinations respecting the dress of the Levitical priesthood. Those substances consequently, which are capable of being applied to ornamental purposes, become, in our mode of using them, a test of virtue, in the same manner as our ordinary clothing, and food, and sleep; all of which, though even necessary to our existence, may be abused by a luxurious indulgence in them. But at present I am no further concerned with the moral part of the question, than to infer that, if

an attention to external ornament be not only allowable, but right, we may antecedently expect that materials for its exercise would be provided by nature: and that is indeed the fact.*

It would be difficult however to determine, which of the three kingdoms, the animal, vegetable, or mineral, is the most prolific source of those beautiful forms and colours which are principally valued as objects of external ornament. We do not indeed observe in any flower that iridescent play of colours which characterises some varieties of the opal and felspar, among minerals; and the plumage of certain birds and the scales of certain fish, among animals: but in elegance and variety of form, and in splendour and simplicity of colour, the vegetable world will be found to yield neither to the animal nor mineral. Mineral substances, however, from their rarity as well as beauty, are more prized; and from the durability of their substance are more permanently applicable to ornamental purposes than those either of animal or vegetable origin; and therefore serve better to illustrate the principle of this treatise.

From among those substances which in commercial language are called precious stones, though some so called are not really derived from the mineral kingdom, it is proposed to select the diamond as a pre-eminent example of the whole class; because, in addition to those properties which render it valuable as an ornamental gem, there are some points in its history which give it a peculiar worth. It will naturally excite the surprise of those, who are unacquainted with the chemical history of this substance, to learn that the purest diamond does not essentially differ from a particular variety of common coal; or from that mineral of which drawing pencils are made, and which is usually, though not with propriety, called *plumbago* and *black lead:* and yet nothing has been more clearly proved than that equal weights of these several substances, if submitted to the process of combustion, will produce nearly equal proportions of carbonic acid gas; which has already been stated to be a chemical combination of definite proportions of carbon and oxygen; the diamond, which is the purest form of carbon, burning away without leaving any residuum; the other two leaving a very small proportion of ashes, in consequence of their containing foreign matter.

And here we can hardly fail to notice a very remarkable instance of what may be called the economical provisions of nature. How rarely, and in what small quantities, are the diamond and plumbago found; and how abundantly does coal predominate in many parts of the world! The Borrodale mine of plumbago in Cumberland is the most considerable source of that substance throughout Europe; and the province of Golconda almost alone supplies the whole world with diamonds: and, probably, the accumulated weight of all the

* "Wherefore did nature pour her bounties forth?" &c.
Comus, line 726, &c.

plumbago and of all the diamonds which have ever been derived from those and other sources, would not equal a hundredth part of the weight of coal which is daily quarried in Great Britain. Suppose now that the case had been reversed; and what would have been the consequence! diamond and plumbago, though really combustible substances, yet from their slow combustibility could never have answered, in the place of coal, as a fuel for general purposes; and, on the other hand, without that large supply of coal which nature has provided, what would have become of the domestic comforts and commercial speculations of the greater part of Europe, during the two last centuries?

The value of the diamond is not derived solely from its transparency and lustre. Its remarkable hardness is another and a most useful property belonging to it: for, in consequence of its great degree of hardness, it is capable of cutting and polishing not only the hardest glass, but even the hardest gems: and if we consider how usuful a substance glass is, how universally employed as a means of at the same time admitting light and excluding the air from the interior of our houses; but that in consequence of its hardness and brittleness it would with great difficulty be divided by any common mechanical instrument, so as accurately to fit the frames in which it is fixed for the above purposes, we at once see the value of a substance which easily and readily accomplishes that end. A small diamond no larger than a mustard seed, brought to a point and fixed in a convenient handle, enables the glazier to cut a plate of glass into pieces of any shape that he pleases: and the same instrument will serve his daily use for many successive years. Nor is it among the least of the glories of this gem, that it gave occasion to that remarkable conjecture of Sir Isaac Newton respecting its chemical nature. That philosopher having observed, that the refractive power of transparent substances is in general proportional to their density; but that, of substances of equal density, those which are combustible possess the refractive power in a higher degree than those which are not, concluded from a comparison of the density and refractive power of the diamond, that it contained an inflammable principle; which opinion was subsequently confirmed by direct experiment. It will be remembered by the chemical reader that on the same ground he made the same conjecture with respect to water, and with the same success. And never, perhaps, did the eye of philosophy penetrate more unexpectedly the thick veil which is so often found to hide the real character of various forms of matter: for, imperishable as from its name the *adamant* was supposed to be, who would have antecedently expected that it might be dissipated into air by the process of combustion? and, with respect to the other subject of his conjecture, if any principle was opposed to combustibility in the opinion of mankind it was water—“Aquæ contrarius ignis.”

Section IV.

The Distribution and relative Proportions of Sea and Land; and the geological Arrangement and physical Character of some of the superficial Strata of the Earth.

As it is clearly a just object of the present treatise to select the most familiar and most obvious instances of the principle intended to be illustrated, I shall in entering upon the abstruse department of geology, consider only those phenomena which offer themselves to the eye in every part of the world; and which are either at once intelligible, or easily demonstrable, to the commonest observer.

Of such phenomena the most prominent are the general distribution of the sea and the land; and the relative proportions of their superficial extent. With reference to the sea, although we may never know all the ends which are answered by its saltness, and why its depth should be greater in some parts than others; and although we can perhaps form no more than a conjecture as to the advantages derivable from the tides; (the prevention, for instance, of a stagnant state of the water;) or from the accumulation of ice near the poles; (the cooling, probably, of the general mass of the atmosphere, and the consequent production of currents of air;) yet of its mode of distribution, and of the relative extent of its surface, we readily apprehend the reason; simply in considering that all those forms of water which contribute to the fertilization of the earth, or the support of animal life, are derived from the ocean. Were the superficial extent of this therefore much less than it is, the quantity evaporated would not be sufficient for the intended purposes; or, were the distribution different from what it is, were the sea, for instance, to occupy one hemisphere, and the land the other, the water evaporated would not be so equally diffused through the atmosphere as it is at present.

And, with respect to the land, how beautifully does the particular arrangement and character of its surface conspire with its general distribution, to equalize the diffusion of the water that is discharged upon it from the atmosphere! The truth of the proposition contained in those lines,

> "Rusticus expectat dum defluat amnis, at ille
> Labitur, et labetur in omne volubilis ævum,"

depends on the nature of the particular arrangement and character, to which allusion has just been made. On the one hand, the general surface of the land ascending from the sea on all sides towards some central ridge or district, called the watershed of the country, all the rain that does not sink beneath the surface is accumulated into rivers;

which naturally descend towards, and ultimately reach, the sea: and, on the other hand, the superficial strata being in general incapable of immediately absorbing the rain which falls upon them, the descent of the water is the necessary result of the inclination of the surface. But if, from partial causes, such an inclination of the land is either wanting, or the course of rivers is impeded by the unrepressed growth of reeds and sedge, the adjoining district is overflowed, and at length converted into a stagnant marsh. It is from such a *physical* cause, that, at this moment, the ancient site of Babylon attests the truth of prophecy; being still, as it has been for ages, "a possession for the bittern, and pools of water."

But that which is called the watershed of any large tract of land is not simply the most elevated portion of the whole surface: it consists also, in a greater or less degree, of ranges of mountains; down the high inclined sides of which the rain immediately descends in numerous torrents, which by their gradual accumulation produce rivers. And, as best calculated to secure the permanent effect, the substance of these mountains is in general so hard, and impermeable to water, that, with reference to the present system of the earth, they may justly be characterised by the epithet "everlasting." But if, instead of being thus durable, they were of a soft or friable substance, they would soon cease to exist as mountains; and if they were porous, instead of compact, they would absorb much of that rain which now contributes to the formation of rivers.

From that portion of the rain which, in comparatively flat districts, sinks beneath the surface of the earth, reservoirs of water are formed: from which, either spontaneous springs arise, or into which, artificial excavations called *wells* are sunk: and of the utility of such reservoirs, those beds of gravel which occur in every part of the world afford upon the whole the best illustration.

Section V.

Beds of Gravel.

Few subjects would at the first view appear more barren of interest than a bed of gravel; consisting, as it usually does, of nothing but fragments of broken pebbles and sand, heaped together in apparently inextricable confusion. Yet such beds, dispersed as they are very generally over the surface of the regular strata, administer materially to the wants of man; in affording him the means of supplying himself readily with that important necessary of life, water.

From the irregularity in the form and size of the component parts of gravel, and from the slight degree of cohesion by which they are united, the whole mass is necessarily porous: and hence, readily transmiting the rain which falls on its surface, becomes charged

with water to an extent proportional to the quantity of rain which has penetrated it; being enabled to retain the water thus accumulated, in consequence of its resting on some substratum, as clay, which is impermeable to water: so that, if an excavation sufficiently deep be made into any part of the gravel, the water immediately drains into this excavation, and rises at length to the level of the general mass of water contained in the whole bed; by which easy process, in such instances at least, those reservoirs, called wells, are formed: and these reservoirs are never exhausted, so long as the whole bed of gravel retains any considerable proportion of water. A very ready illustration of this fact is afforded by the familiar instance of those excavations which children are accustomed to make in the sand of the sea-beach, while yet charged with moisture during the ebbing of the tide.

The inhabitants of a town which, like Oxford, is built partly on a comparatively shallow bed of gravel, and partly on a deep stratum of clay, can well appreciate the value of the former substratum of their habitations, with reference to the facility of procuring water: for while they, whose dwellings are built on the gravel, can readily obtain water by sinking a well immediately on the spot; they whose dwellings are on the clay, must either procure water from a distance, or incur a very serious, and, finally perhaps, useless expense, in attempting to penetrate the clay.* With respect to its general uses, gravel seems only to be employed in the repairing of roads and walks; in the composition of some kinds of mortar; and as a convenient occasional ballast for sailing vessels: so that, if we confine our view to the means afforded by gravel beds of supplying the ordinary wants of man, their history may be comprised in a few words. Not so, if we view them with reference to their origin, and the nature of their occasional contents: and little dreams any one, save the professed geologist, what a mine lies hid, in those confused heaps of ruin, for the exercise of man's intellectual faculties. Few subjects indeed have afforded ampler scope for philosophical reflection. In proof of which I need do no more than refer to the labours and ingenuity of Cuvier on the continent, and of Professor Buckland in our own country: of whom the one, by a scientific examination of the organic remains of gravel beds, in addition to those of some of the regular strata, has brought to light not only numerous individual species, but whole families of animals, which have ceased to exist ages and ages since: and the other, with no less labour and ingenuity, has all but exhibited some of these animals to our view in the very act of devouring and digesting their food.

How often, and with what intense interest, has not the scientific

* From the observation of analogous arrangement in the general strata of the earth, namely, that those which are pervious to water alternate with those which are impervious to water, Mr. William Smith, "the father of English geology," became acquainted with the origin of springs, and the true principles of draining.

geologist perused the original essays of Cuvier; in which, setting out from the casual observation of a simple fragment of a fossil bone belonging to some extinct species, he has established not only the class and order, but even the size and proportions of the individual to which it belonged, and the general nature of its food. And how often, in addition to professed geologists, has not an attentive audience of academical students listened with admiration to the clear and vivid eloquence of the other of those philosophers, the Geological Professor of Oxford, while he unfolded that beautiful chain of facts by which he traced his antediluvian animals to their native caves; and exposed to view, to the mental eye at least, and almost to the corporeal, their particular habits, and even the relics of their last meal. And, lest there should be any doubt as to the nature of this meal, he discovered, by a most philosophical, for I will not say fortunate conjecture, unequivocal proofs of the actual remains of it; not only in its original, but also in its digested state. I here allude particularly to his verifications of the masses of digested bone which he has most satisfactorily shown to have passed through the whole tract of the digestive organs of his favourite hyenas; and which are so nearly identical, in every character, with the similar masses that daily traverse the same organs of the living species, as to make it difficult even for an experienced eye to ascertain the difference between them.

It is natural that I should feel a pleasure in recording the well-earned fame of a friend with whom I have lived in habits of intimacy for more than twenty years; and whom, in the commencement of his career, I had the good fortune to lead into that avenue of science, on which he has subsequently thrown more light than perhaps any other English geologist; with the exception indeed of one, the reverend W. Conybeare, the admiration of whose comprehensive and commanding views, as well in fossil as in general geology, is not confined to his own countrymen; the members of the French Institute having attested their sense of his pre-eminent talents by the high honour of selecting him, a few years since, as one of their foreign associates—an honour particularly distinguished by the uncommon circumstance, that it was not only unsolicited, but unexpected, by himself.

On one point, however, of Professor Buckland's general theory of the organic remains met with in gravel beds, and in certain natural caverns, I not only differ from him, but think it right to express the ground of that difference. Dr. Buckland's arguments in favour of his opinion that the animals of the gravel beds, and the caverns, habitually frequented the spots where these remains are found, are not only ingenious, but are occasionally supported by facts which almost necessarily lead to that conclusion: and it is not intended to attempt to invalidate them. They do not indeed stand in the way of the objection now to be advanced: this objection being applicable to that part of theory only which considers the destruction of

these animals as the effect of the Mosaic deluge. Nor is the objection, in its origin, so much directed against the insulated supposition that these organic remains are immediate proofs of the Mosaic deluge; as against the *principle* of supporting the credibility of the sacred Scriptures on any unascertained interpretation of physical phenomena. Such a support appears to be imprudent, as well as unnecessary: uunecessary, because the moral evidence of the credibility of the Scriptures is of itself fully sufficient; imprudent, because we have the strong ground of antecedent analogy, not only in another but in this very branch of knowledge, for anticipating a period in the progress of science, when particular phenomena may be interpreted in a very different manner from that in which they are intepreted at present. Thus the explanation of the motions of our solar system, which is now admitted very generally, without any fear of weakening the authority of Scripture, was once as generally impugned on the principle of that very fear. Time was also, and indeed within the last century, when the shells and other organic remains, which are imbedded in the chalk and other solid strata, were considered to be the remains and proofs of the Mosaic deluge; and yet at the present day, without any fear of injuring the credibility of the Scriptures, they are admitted very generally to have been deposited anteriorly to the Mosaic deluge. And who will venture to say, in the infancy of a science like geology, that the same change of opinion may not happen with respect to the organic remains of the gravel beds and caverns. Nor indeed do I think, and I expressed this opinion nearly twenty years since, that the organic remains of the gravel beds and the caverns can be, on even mere philosophical grounds, adduced as physical proofs of the Mosaic deluge. For as according to the Mosaic record it was the intention of the Deity on that occasion, in the midst of a very general destruction of *individuals* to preserve *species*, we should in reason expect, among the organic remains of that catastrophe, a preponderance, at least, of the remains of existing species: since, although some species may have been lost subsequently to the deluge, these naturally would be comparatively few. But the fact is just the reverse; for by far the greater number of the organic remains of the gravel, as of the caverns, belong to species not known now to exist. And with respect to those remains which appear capable of being identified with living species, Cuvier allows that they belong to orders of animals, the species of which often differ only in coulor, or in other points of what may be called their external or superficial anatomy; and cannot therefore be satisfactorily identified by the remains of their bones alone.

I do not consider it right to enter into a more extended examination of the question on the present occasion: but, could it be proved that *visible* traces of the Mosaic deluge must necessarily exist, arguments might be adduced to show both where those traces ought to be expected, and that they do actually exist. But the deluge itself was evidently

a miracle, or an interference with the laws which usually regulate the operation of second causes: and whoever admits the force of the reasoning, contained in Butler's Analogy of Natural and Revealed Religion, will be disposed to allow that *visible* evidence of the catastrophe may have been purposely obscured, in order to exercise our faith in an exclusive belief of the *moral* evidence.

I would not lay undue weight on the negative proof arising from the absence of human remains, although they have been in vain searched for, even in parts of the world to which it may fairly be presumed that the human race had penetrated at the period of the Mosaic deluge: but undoubtedly such a negative proof is not without considerable weight; especially when taken in connexion with the theory of a continental geologist, M. de Beaumont, of whose powers of philosophical generalization Professor Sedgwick speaks in language the most expressive. "I am using," he say, "no terms of exaggeration, when I say that, in reading the admirable researches of M. de Beaumont, I appeared to myself, page after page, to be acquiring a new geological sense, and a new faculty of induction."*

After having taken a general survey of M. de Beaumont's observations and views, Mr. Sedgwick alludes to an opinion which he himself had expressed in the preceding year, that what is commonly called diluvial gravel is probably not the result of one but of many successive periods. "But what I then stated," he adds, "as a probable opinion, may, after the essays of M. de Beaumont, be now advanced with all the authority of established truth—we now connect the gravel of the plains with the elevation of the nearest system of mountains; we believe that the Scandinavian boulders in the north of Germany are of an older date than the diluvium of the Danube: and we can prove that the great erratic blocks, derived from the granite of Mont Blanc, are of a more recent origin than the old gravel in the tributary valleys of the Rhone. That these statements militate against opinions, but a few years since held almost universally among us, cannot be denied. But, in retreating when we have advanced too far, there is neither compromise of dignity, nor loss of strength; for in doing this, we partake but of the common fortune of every one who enters on a field of investigation like our own. All the noble generalizations of Cuvier, and all the beautiful discoveries of Buckland, as far as they are the results of fair induction, will ever remain unshaken by the progress of discovery. It is only to theoretical opinions that my remarks have any application." (p. 33.)

Mr. Sedgwick then proceeds to argue that different gravel beds having been formed at different periods, it may happen from the nature of diluvial action, that mixtures of the materials of different beds may occur; and consequently that "in the very same deposite we

* See Prof. Sedgwick's address to the Geolog. Society, 1831, p. 29.

may find the remains of animals which have lived during different epochs in the history of the earth." (p. 33.)

He then shows how, from the double testimony of the widely existing traces of diluvial action, and the record of a general deluge contained in the sacred Scriptures, the opinion was naturally formed that all those traces were referable to one and the same action: though we ought in philosophical caution to have hesitated in adopting that opinion, because "among the remnants of a former world, entombed in these ancient deposites, we have not yet found a single trace of man, or of the works of his hands." (p. 34.) Lastly, he strenuously denies that the facts of geological science are opposed to the sacred records, or to the reality of an historic deluge; and for himself, utterly rejects such an inference: and argues justly, that there is an accordance between the absence of human remains in these diluvial beds of gravel, and the supposed antiquity of their formation, inasmuch as the phenomena of geology, and the testimony of both sacred and profane history, "tell us in a language easily understood, though written in far different characters, that man is a recent sojourner on the surface of the earth." (p. 35.)

Section VI.

Metals.

The atmosphere, and the vegetable, and animal kingdoms, being three out of the four general departments of the external world, are most extensively necessary to the welfare, if not to the very existence, of every individual: but even communities of men, in an uncivilized state indeed, have existed, and in some parts of the earth are still existing, without any further aid from the mineral kingdom than that, which the common soil affords to the growth of the food which supports them. But a civilized state of society is the natural destination of man; and such a state of society is incapable of arising or being maintained, without the aid of mineral substances: and this assertion holds more particularly with respect to the *metallic* species.

In that department of civilized intercourse which exists in the exchange of the commodities of life, what other substance could be an equivalent substitute for gold and silver, or even copper, as a medium of that exchange? In what constant use, and of what immense importance, are some of the commonest metals in agriculture, and in the arts; or for the various purposes of domestic life! Nor have any substances more successfully exercised the powers of the mind, in the discovery or improvement of physical truths; or more largely contributed to the benefit of mankind by the practical application of those truths. We owe it to the researches of philosophy, not only that new and highly valuable metals have been discovered; but that

the general value of the metals previously known, has been advanced by extended and improved applications of their inherent properties, or by the invention of new metallic combinations or alloys.

If a convincing and familiar proof of the extensive application of the metals to the common purposes of life were required, we need only refer to the case of many a common cottager, who could not carry on his daily concerns and occupations without the assistance of several of the metals. He could not, for instance, make his larger purchases, nor pay his rent, without silver, gold, and copper. Without iron he could neither dig, nor plough, nor reap; and, with respect to his habitation, there is scarcely a part of the structure itself, or of the furniture contained in it, which is not held together, to a greater or less extent, by means of the same metal: and many articles are either entirely of iron, or of iron partially and superficially coated with tin. Zinc, and copper, and antimony, and lead, and tin, are component parts of his pewter and brazen utensils. Quicksilver is a main ingredient in the metallic coating of his humble mirror: cobalt and platina, and metals perhaps more rare and costly than these, as chrome, are employed in the glazing of his drinking cups and jugs. And if he be the possessor of a fowling-piece, which commonly he would be, arsenic must be added to the foregoing list, as an ingredient in the shot with which he charges it; for it is arsenic which enables the shot, during the process of its granulation, to acquire that delicately spherical form by which it is characterised. So that the whole number of metals made use of by society at large for common purposes, amounting to less than twenty, more than half of these are either directly used by the mere peasant, or enter into the composition of the furniture and implements employed by him.

In estimating the value of those mineral substances which were considered in the preceding chapter, as applicable to the common purposes of life, their degree of hardness is the property of principal consideration: but, in addition to this, metallic bodies possess some peculiar properties which very greatly increase their value. Thus, under a force acting perpendicularly on their surface, as under repeated blows of the hammer, or compression by rollers, many of them are capable of being expanded to a greater or less extent; some of them to such an extent as to become thinner than the thinnest paper; which property in its various degrees is expressed by the term *malleability*: others, though not possessing any great degree of malleability, may be drawn out into a wire, sometimes so fine as scarcely to be visible by the naked eye; which property is expressed by the term *ductility*. All of them are capable of being expanded or contracted in every direction by an increase or decrease of their temperature; the degree of this *expansibility*, as of its opposite effect, depending on the degree of the temperature. And lastly, in connexion with certain points of temperature, all the metals are capable of existing either in a solid or in a liquid state: and their property

of passing from a solid to a liquid state, in consequence of the agency of heat, is called their *fusibility.*

Into the detail of the different degrees in which these properties are possessed by different metals, it belongs to the chemist to enter. What we have at present to consider is, the advantage accruing to society from these properties themselves, and from their existence in that particular degree in which they actually do exist in the different metals: to show, for instance, that those metals which possess malleability in a greater ratio than ductility, or ductility in a greater ratio than malleability, are of infinitely greater value than if the converse were true: and so with respect to the property of fusibility. Thus gold, being comparatively scarce, and principally valuable on account of its colour, its resplendency, and its remarkable power of resisting the action of the air, and of various agents which readily tarnish or rust the more common metals, (all which properties reside on the mere surface,) a given quantity of such a metal is consequently more valuable in proportion to the degree of its malleability; because it may be extended over a greater surface: and no metal possesses this property in so high a degree as gold; so that, as far as the eye is the judge, the most ordinary substance may be made to represent the most costly, at a comparatively trifling expense: while in the degree of its ductility, which in gold would be, for general purposes, of little moment, it is inferior to most of the metals.*

Iron, again, is malleable to a degree which renders it most valuable as a material for fabricating all kinds of instruments for mechanical, domestic, or philosophical purposes; and it is capable of being hardened by well known processes sufficiently for the numerous and important works of the carpenter and mason, and the equally important purposes of war, agriculture, and the arts. A greater degree of malleability, in a metal employed for such purposes as those for which iron is usually employed, especially as this metal is very easily corroded by rust, would clearly have added nothing to its practical value: while its degree of ductility, which exceeds that of every other metal, combined with its capability of being hardened in various degrees, occasionally confers a value on it greatly superior to that of gold.

From the difference in the degree of fusibility of different metals, aided by the disposition which they have to unite so as to form an alloy, arises the possibility of covering one metal in a solid state with a superficial coating of another metal in a state of fusion. I am not aware that this method is employed, at least to any extent, in any

* It should be kept in mind that this observation is applied to unalloyed or pure gold; for, when alloyed, this metal is capable of being drawn out into a comparatively fine wire. Dr. Wollaston indeed suggested a method of drawing out even pure gold into an exceedingly fine wire, by enclosing it in a mass of a highly ductile metal, drawing out the mixed metal into fine wire, and disengaging the gold from the metal in which it was enclosed, by any acid which would dissolve the latter without affecting the gold itself.

other instances, than in the application of tin to the surface of copper or of iron: but, were there a hundred similar instances, they would not lessen the value of this, as affording an illustration of that principle which has been borne in mind throughout this treatise. Consider only the respective degree of abundance of each of the three metals just mentioned, and the difference in some of their qualities with respect to external agents, and we shall have ample reason for being assured that, on this and on every other occasion, we may say of the Creator of material things—"In wisdom hast Thou made them all." And not only is it true that

"The world by difference is in order found;"

but the difference is so adjusted in every instance, that, if it were varied, the value of the substances in which the difference is observable would be destroyed. Thus, of the three metals now under consideration, iron and copper, from the degree of their malleability, are easily formed into those various vessels which are of daily use for culinary and other purposes; while tin possesses the property of malleability in comparatively a slight degree: and, correspondently with the extent of their use, iron and copper are found in great abundance and in almost every part of the world; while tin is of very rare occurrence. Again, the two former metals are easily rusted; and, from the poisonous quality of the rust of copper, fatal effects on human health and life would be frequently occurring, used so extensively as that metal is for the construction of vessels in which our food is prepared, were it not defended by that superficial coating of tin, which is commonly applied to the inner surface of such vessels; tin being neither easily rusted, nor capable of communicating any poisonous quality to substances brought into contact with it. Let us then suppose that the respective degree of malleability, or of fusibility, were reversed in these metals; and observe the inconvenience that would ensue. Let the tin have that degree of malleability, for instance, which would render it capable of supplying the place of the iron, or the copper, in the construction of various economical vessels and instruments; yet, from the small quantity in which it occurs in the world, the supply of it would soon be either exhausted, or its price would be so enhanced that it could not be purchased except by the rich. And, even if the supply were inexhaustible, yet, from the softness of the metal, the vessels made of it would be comparatively of little use; and from the low temperature at which it melts, it could not be readily used for the generality of those purposes to which copper and iron are commonly applied. On the other hand, let the copper or the iron be as fusible as tin; and let the tin be as refractory under the action of heat as iron and copper are: in that case, how could the tin be applied with any degree of economy to the surface of either of the other two; while they themselves would be unfit, from their easy fusibility, to withstand that degree of heat

to which they are necessarily exposed in many of the economical uses to which they are applied?

There remains to be considered one property of metals with respect to their fusibility, which is of the highest practical importance; for on this property depends the possibility of uniting together portions of the same, or of different metals, without fusion of the metals themselves. If two metals be melted into one uniform mass, the compound is called an *alloy;* and in the greater number of instances, if not in all, the alloy is more readily fusible than either of the component metals: and hence it easily becomes a bond of union between the two metals, or different portions of either of them. Such an alloy, when so employed, is called a *solder*. In considering the present subject, we cannot overlook a remarkable analogy between metallic substances and building stones, with reference to one mode in which they may respectively be united to each other, so as to form one solid mass; mortar being to stones what solder is to metals. Thus, in uniting two metallic surfaces by means of solder, it is requisite that the latter should be in a fluid state, or melted; and, in uniting the surfaces of two bricks or stones by means of mortar, the latter must be, if not in absolutely a fluid, yet in a soft and yielding state: and the final hardening of each is the efficient cause of permanent union. The period indeed requisite for the due consolidation of the uniting medium is very different; the solder becoming fixed in a few seconds, the mortar requiring some hours, perhaps days, for its consolidation: but, in the end proposed, there is no essential difference; for the mortar, if originally tempered well, and well applied, as firmly unites the stones, as solder the metals: so that mortar might be called a slowly acting solder; and solder, an extemporaneous or quickly acting mortar.

It would appear a paradox, if not an absurdity, to affirm abruptly that a liability to rapid decay is among the most important properties of any substance in general use: and yet this may be truly affirmed of iron. For though, in one sense, its liability to rust diminishes the value of this useful metal, because it is consequently almost impossible to preserve it very long in an entire state; yet, indirectly, this property, though detrimental to individuals, is beneficial to the community: for, in the first place, the presence of iron ore is so general, and its quantity so abundant, that there is no probability of any failure in its supply: and, in the next place, numerous branches of trade are kept in continued employ, both in working the ore, and in meeting the constantly renewed demand for implements made of iron, owing to the rapid corrosion of this metal.

Among the metals there is one, the history of which ought not to be overlooked on the present occasion, from the very circumstance that its value in a great measure depends on the absence of most of those properties which render all other metals valuable. Quicksilver is the metal in question: and what an anomaly does it not present in

the general history of metals; existing, under all common variations of temperature, in a fluid state, while all other metals, with which we are familiar, are, under the same variations, solid; nor indeed are they capable of becoming fluid, but by an elevation of temperature to which they are hardly liable to be exposed, unless designedly: lastly, in consequence of its fluidity, destitute of malleability and ductility; which are among the most valuable properties of the metals taken collectively? This state of fluidity, however, is the very point on which the value of this metal in a great measure turns: for hence it is successfully employed for many purposes, to which, were it solid, it would be inapplicable. How valuable is its use in the construction of the common thermometer and barometer; the value, in the case of the former instrument, depending entirely on its fluidity, and on the physical characters of the fluid itself—the equable ratio, for instance, of its contraction and expansion under widely varying degrees of temperature; and its property of remaining fluid through a greater range of temperature than any other known substance.* And, in the case of the barometer, what fluid is there which could supply the place of quicksilver, with any degree of convenience? since, from the great specific gravity of this metal, a column of the perpendicular height of about thirty inches, sufficiently answers the intended purpose; which column in the case of almost every other fluid, would amount to as many feet. And as, in such a case, the column must necessarily be contained in a glass tube, in order to make the alterations in its height visible, how would it be possible to render such an instrument portable? and yet, if not portable, it would often be of no use when most wanted.

In those numerous philosophical experiments in which it is requisite to insulate portions of various gaseous substances, for the purpose of examining their properties, how could the experimentalist proceed without the use of the metal now under consideration; which by its fluidity readily yields its place to the various kinds of gas which are to be transferred to vessels previously filled with the quicksilver; and, having no chemical affinity for the greater number of gaseous substances, is calculated to retain them in an insulated and unaltered state for an indefinite length of time? nor let us forget to observe, how the properties of the metal, which is necessarily in contact with the gaseous substances in question, conspire with the properties of the glass vessels containing these gaseous substances, to facilitate the observations of the philosopher: for, if the glass were not both a transparent body, and equally devoid as the quicksilver of any chemical affinity for the gas contained in it, the metal itself would be of

* Quicksilver does not become solid till exposed to a temperature of about seventy degrees below the freezing point in the scale of Fahrenheit; nor does it pass readily into a state of vapour till exposed to a temperature equal to nearly three hundred and seventy degrees above the boiling point of water, on the same scale.

little use for the purpose intended; since we are not acquainted with any other substance that could supply the place of glass—with the exception perhaps of rock crystal; which however could only be procured in small quantity any where, and could not be worked into a convenient form but at a most enormous expense.

Section VII.

Common Salt, &c.

It does not appear that the mineral kingdom contains a single species capable of being employed as food: but there is one mineral species, which indirectly contributes to the nourishment of many other animals as well as man; and that is common salt: the flavour of which, to a certain extent, is not only grateful to the palate, but, practically speaking, mankind could not exist, or at least never have existed, without the constant use of it. Thus, though employed in very small quantities at a time by any individual, and almost exclusively for the purpose either of preserving or of rendering his food more palatable, this substance may fairly be classed among the principal necessaries of life: and, correspondently with this statement, we find that nature has supplied it in abundance, indeed in profusion often, in various parts of the globe: for, to say nothing of those apparently inexhaustible masses which occur among the solid strata of the earth, and which have been constantly quarried through successive ages from the earliest records of history, the ocean itself is a never-failing source of this valuable substance. In other instances salt springs afford the means of a ready supply: and, throughout a considerable part of the sandy districts of Africa and Asia, the soil itself abounds with it.* The abundant supply of common salt coincides with its extensive utility. It is every where indispensable to the comforts of man; and it is every where found, or easily obtained by him. And, though not to the same extent, the same observation holds with reference to many other natural saline compounds. Thus carbonate of potash, and natron or carbonate of soda, alum, borax, sal ammoniac, and sulphate of iron, or green vitriol, which are most

* It does not belong to our present purpose to describe the common processes by which the salt is obtained either from the sea, or from any other liquid that may hold it in solution: but the following account of a particular process, for this purpose, so well illustrates the ingenuity of the human mind in taking advantage of natural hints, if the expression may be permitted, that no excuse can be necessary for its introduction. In Guiana there is a very common species of palm, the flowers of which are enveloped by a sheath capable of holding many pints of water; and the density and general nature of the sheath is such, that the water contained in it may be heated over a fire without destroying its substance: and the Caraibs actually employ these sheaths, in evaporating the sea-water for the purpose of obtaining a quick supply of salt. (Diction. des Sciences Nat. tom. xxxvii. p. 283, 4.)

extensively useful salts in many processes of the arts, are either found abundantly in various parts of the world, or may be obtained by very easy means: while a thousand other saline compounds, which are rarely of any practical importance, are scarcely known to exist in a native state. And it is probable that that useful metal, copper, in consequence of its frequent occurrence in a native state, was employed long before the mode of reducing iron from its ores had been discovered; as Werner (and Hesiod, and Lucretius, ages before him*) conjectured.

CHAPTER VIII.

ADAPTATION OF VEGETABLES TO THE PHYSICAL CONDITION OF MAN.

Section I.

General Observations on the Vegetable Kingdom.

The vegetable kingdom has this distinction with reference to the subject of the present treatise, that its productions are amongst the first objects that forcibly attract the attention of young children; becoming to them the source of gratifications, which are among the purest of which our nature is capable; and of which even the indistinct recollection imparts often a fleeting pleasure to the most cheerless moments of after-life.

Who does not look back with feelings, which he would in vain attempt to describe, to the delightful rambles which his native fields and meadows afforded to his earliest years? Who does not remember, or at least fancy that he remembers, the eager activity with which he was used to strip nature's carpet of its embroidery, nor cease to cull the scattered blossoms till his infant hands were incapable of retaining the accumulated heap? Who, on even seeing the first violet of returning spring, much more on inhaling its sweetness; or in catching the breeze that has passed over the blossom of the bean or of the woodbine, does not again enjoy the very delights of his early childhood?

It may be said indeed that the pleasure of such recollections is for the most part of a moral and intellectual nature; and, so far, is

* Χαλκῷ δ' ἐργάζοντο, μέλας δ' οὐκ ἔσκε σίδηρος.

ΕΡΓ ΚΑΙ ΗΜ. line 151.

Posterius Ferri vis est, Ærisque reperta.
Et prior Æris erat quam Ferri cognitus usus.

Lucret. V. 1285.

foreign to our present object: but the pleasure of the original enjoyment appears to be principally of a physical character; and is no doubt intended to produce, at the moment, a highly beneficial, though merely physical effect: for while the eye of the child is attracted by the unexpected forms and colours of the plants and flowers presented to his view, and his mind is instigated to gratify the eager desire of possessing them, he necessarily subjects his limbs to that degree of exercise and fatigue, which contributes to the general health of his body. Nor let such pleasures be undervalued in their consequence: they give that moderate stimulus to the whole system, which even the early age of infancy requires; and, by shutting out the listlessness that would arise from inactivity, they become eventually the source of moral and intellectual improvement.

With reference to the primary wants of mankind at large, the vegetable kingdom is of the highest importance. Let the earth cease to produce its accustomed fruits, and every form of animal life must be soon annihilated: for all animals either derive their nourishment directly from vegetable food, or feed on those animals which have themselves fed on vegetables. And, without the aid of the same productions, we should be deprived of various substances which are now employed for clothing, and fuel, and the construction of our habitations. But the adaptation of the vegetable kingdom to the arts and conveniences of life is visible in numerous other instances: and the principal difficulty, in illustrating this point, is the selection of appropriate examples, and the order of their arrangement.

Section II.

The Cocoa-nut Tree, including the formation of Coral Reefs.

For the purpose of introducing in a more particular manner the general subject of this chapter, and as an impressive example of the important ends which nature often accomplishes by the simplest means, I propose to consider the mode in which the cocoa-nut tree is spontaneously propagated in the coral islands of the Indian Archipelago and elsewhere: nor will it be an undue anticipation of a subsequent department of this treatise, if I previously give a brief description of the process by which those islands have themselves been brought into existence. The account of their origin indeed belongs more strictly to the history of the animal than of the vegetable world; but the two subjects are so naturally connected, that it would be injudicious to separate them.

It may be collected from the observations of the French navigator, M. Péron, (Ann. du Mus. tom. vi. p. 30, &c.) that almost all those countless islands of the Pacific Ocean, which are found to the

south of the equator between New Holland and the western coast of America, are either entirely or in part made up of coral: and all the adjacent ocean abounds with coral reefs, which, constantly augmenting, are constantly changing the state of bays, and ports, and gulfs; so that new charts are continually required for the same coasts. From Barrow also it appears, (Barrow's Cochin China, p. 167,) that the formation of coral reefs or isles is very common in the tropical parts of the Eastern and Pacific Ocean. And Captain Flinders says that the quantity of coral reefs between New Holland and New Caledonia and New Guinea, is such, that this might be called the *Corallian Sea.* (Flinders's Voyage, vol. ii. p. 314).

Many more references might be made, to others as well as the above-mentioned voyagers, in order to show that the formation of coral islands is effected by nature on a very extensive scale: but, for the present purpose, the preceding references may be considered sufficient. Let us now therefore describe the general character and mode of formation of these islands.

Forster says* that the low islands of tropical seas are commonly "narrow, low ledges of coral rock, including in the middle a kind of lagoon; and having here and there little sandy spots, somewhat elevated above the level of high water, on which cocoa-nuts thrive:" correspondent with which description is the account given by Captain Cook, on the occasion of discovering one of these coral reefs; which was at first mistaken by him for land. "This proved to be," he says, "another of those low or half-drowned islands, or rather a large coral shoal, of about twenty leagues in circuit. A very small part of it was land, which consisted of little islets ranged along the north side, and connected by sand-banks and breakers. These islets were clothed with wood, among which the cocoa-nut trees were only distinguishable. We ranged the south side of this shoal at the distance of one or two miles from the coral bank, against which the sea broke in a dreadful surf. In the middle of the shoal was a large lake, or inland sea, in which was a canoe under sail." (Cook's Voyage, 4to. 1777. vol. i. p. 141, 142.)

Coral, considered as an individual substance, is a natural form of carbonate of lime, produced by an animal of the polype kind. The particles of carbonate of lime, however produced, are cemented together so firmly by a glutinous secretion of the same animal, as to acquire a degree of consistence, which not only forms a safe habitation for a race of animalcules, from their soft texture most obnoxious to external injuries; but which is calculated to resist the utmost action of the sea, and in many instances to protect the original surface of the earth itself from its assaults. Thus almost all the tropical islands, which Cook saw in the South Pacific Ocean, are guarded from the sea, to a greater or less extent, by a reef of

* Forster's Voyage round the World, p. 14, 15.

coral rocks, extending out from the shore to the distance of six hundred feet and farther; and on this reef the force of the sea is spent before it reaches the land: and thus nature has effectually secured these islands from the encroachments of the sea, though many of them are mere points when compared with that vast ocean.*

As the specific gravity of coral is greater than that of sea-water, the structure of a coral reef necessarily commences either from the natural bed of the ocean, or from the surface of some submarine rock; and, as may be collected from the nature of the soundings among coral reefs, the whole structure is very frequently disposed in the form of a crescent; sometimes even approaching to a circle. This crescent is, on the convex side, built up throughout in very nearly a perpendicular direction; so as to form a wall, which is exposed to that quarter from whence a stormy sea most frequently prevails. The interior of the structure seems gradually to shelve off; so that about the centre of the inclosed, or partially inclosed space, the sea is found of its natural depth. Correspondently with such an arrangement, it happens usually that the soundings gradually lessen from the centre of the area inclosed by a coral reef, towards the exterior ridge; and then suddenly sink to two hundred fathoms or more.

To the foregoing observations I shall subjoin the opinion of Captain Flinders on the process observed by nature in the formation of coral reefs. "It seems to me," he says, "that when the animalcules, which form the coral at the bottom of the ocean, cease to live, there structures adhere to each other by virtue either of the glutinous remains within, or of some property in salt water; and the interstices being gradually filled up with sand and broken pieces of coral washed by the sea, which also adhere, a mass of rock is at length formed. Future races of these animalcules erect their habitations upon the rising bank, and die in their turn; to increase, but principally to elevate, this monument of their wonderful labours. The care taken to work perpendicularly, in the early stages, would mark a surprising instinct in these diminutive creatures. Their wall of coral, for the most part in situations where the winds are constant, being arrived at the surface, affords a shelter; to leeward of which their infant colonies may be safely sent forth: and to this, their instinctive foresight, it seems to be owing, that the windward side of a reef, exposed to the open sea, is generally, if not always, the highest part; rising almost perpendicularly, sometimes from the depth of two hundred and perhaps many more fathoms. To be constantly covered with water seems necessary to the existence of the animalcules; for they do not work, except in holes upon the reef, beyond low water-mark: but the coral sand, and other broken

* Cook's Voyage, 1777, 4to. vol. i. p. 212.

remnants thrown up by the sea, adhere to the rock, and form a solid mass with it, as high as the common tides reach. That elevation surpassed, the future remnants, being rarely covered, lose their adhesive property; and, remaining in a loose state, form what is usually called a *key* upon the top of the reef. The new bank is not long in being visited by sea birds; salt plants take root upon it, and a soil begins to be formed; a cocoa-nut, or the drupe of a pandanus, is thrown on shore; land birds visit it, and deposite the seeds of shrubs and trees; every high tide, and still more every gale, adds something to the bank; the form of an island is gradually assumed; and, last of all, comes man to take possession."*

In the base of a coral island of the above description, Captain Flinders distinguished not only the sand, coral, and shells, formerly thrown up, in a more or less perfect state of cohesion; but also small pieces of wood, pumice-stone, and other extraneous bodies, which chance had mixed with the calcareous substances when the cohesion began, and which in some cases were still separable from the rock without much force.† Such sand-banks are found in different stages of progress; some being overflowed with every returning tide; some raised above high-water mark, but destitute of vegetation; some, lastly, habitable and abounding in trees.

Let us here pause for a moment to contemplate the wonderful effect produced by apparently the most inadequate means. And wonderful indeed is the effect, even if the process above described were now to cease for ever; but much more, if we look to its probable extension: for, reasoning on what has already been accomplished, and on what is at this moment rapidly advancing, it is evidently probable that a new habitable surface of land may be eventually produced, equal in extent to the whole of Europe, and produced by the agency of a tribe of animals, which occupy very nearly the lowest steps in the scale of animal creation, and which in every other respect are the most inefficient and helpless of creatures. For, fixed as they are, both individually and collectively, to a completely local habitation; or, rather, buried as it were in a strong mass of coral, and literally

"Each in his narrow cell for ever laid,"

their general appearance and mode of growth so little resemble the animal character, that, for a long time, many of the species were considered as of vegetable origin; and are, even now, very commonly called *zoophytes*, or animated plants.

Nor let us fail to observe, in the foregoing account, the physical fitness for each other of two very different departments of nature. The same geographical climate which gives birth to those animals,

* Flinders Voyage, vol. ii. p. 115, 116. †Ibid, p. 116.

whose labours produce this previously unexpected habitable surface, gives birth also to those vegetables, which, at the same time that they are capable of growing on so loose and poor a soil, are capable besides of supplying its future inhabitants not only with nutritious food, both in a liquid and a solid form, but with materials for constructing their habitations, and for many other useful purposes. And in the mean time the fowls of the air, and the very winds and waves, are all employed in administering to the beneficent intentions of Providence. Of little use would be a new habitable surface, were it never to be tenanted by human beings; and in vain would man attempt to colonize that surface, were it barren of vegetable productions: but the seeds of various plants, as we have seen in the foregoing descriptions, are either brought by birds, or drifted by the wind and waves, to a soil calculated to support them.

Among the vegetable productions of coral islands, the cocoa-nut tree stands pre-eminent in value; containing in itself nearly all those important properties, which are found at large in that natural family of plants, the palms: and valuable indeed are those properties, if we may rely on the accounts which have been given of them by different authors; and of the truth of those accounts there is no sufficient reason to doubt. Johnston,* speaking of the abundance of the cocoa-nut tree in India, where he says it occurs to a greater extent than the olive in Spain, or the willow in Holland, affirms that there is no part of the tree which is not applied to some useful purpose. Not only the cabins of the poorer natives, but large houses, are constructed entirely with materials afforded by this tree; the trunk, when split, supplying rafters, &c.; and the leaves, when plaited, making roofs and walls, which are impervious to wind and rain. The statement of Johnston is confirmed by captain Seely, in his account of Ellora†, who says that "when he was stationed at Goa, in 1809, he lived, as many others did, in a cocoa-nut leaf house; and that although the period was in the very height of the monsoon, and the house was on the sea-coast, it was comfortable and warm. He believes that not a nail was used in the whole building: the rafters and supporters, &c. were fastened on with string made of the fibrous envelope of the cocoa-nut shell; the wood was the tree itself; the roof, walls, doors, and windows were the leaf." From the same anthority we learn that the fibres, enveloping the shell of the nut, may be woven into a cable by which ships of seventy-four guns have safely rode out heavy gales, when European cables have parted.

In the Wernerian Memoirs, vol. v. p. 107, &c., is a very interesting account of the cocoa tree; in which the author states that this tree will grow on the sand of the sea-shore, where scarcely anything else will vegetate: which corresponds with the account of an author above-mentioned, who, speaking of its growth, says, "radicem

* Johnstonus de Arboribus, p. 146, &c.

† London, 1824, 8vo. p. 284.

habet tenui spatio porrectam; et quæ quasi contra fidem terræ inhæret."* And these statements are quite in accordance with the observations of captain Flinders.

From other sources we learn that this tree bears fruit twice or thrice in the year;† that the half-ripe nut contains sometimes three or four pints of a clear aqueous fluid, fragrant, and pleasant to the taste; and that the nut itself, from its highly nutritious qualities, is used as an aliment in all inter-tropical countries.‡ In the volume of the Wernerian Memoirs above-mentioned, it is said that in 1813 the number of cocoa trees cultivated in Ceylon, along a line of coast of about 184 miles, was ten millions, and that that number was increased in following years; that this tree is fruitful from its eighth to its sixty-fourth year, and sometimes bears from eighty to one hundred nuts annually; that elephants are fed on cocoa nut leaves; and that the ashes of the tree contain so great a proportion of potash, that the native washermen of Ceylon use them instead of soap.§

In the Nouv. Dict. d'Hist. Nat. tom. vii. p. 297, &c. it is stated, that, as in other palms, if the extremity of the sheath from whence the flowers of the cocoa arise be cut off while young, a white sweet liquor distils from it, which is used extensively as a beverage in India under the name of *palm wine;* that this liquor, if concentrated by boiling, deposites a sugar; that if exposed to the air it acquires vinous properties at the end of twelve hours, and at the end of twenty-four hours becomes vinegar; that an oil may be obtained from the nut, which is not inferior to sweet almond oil, and which is used almost exclusively in India; and that the shell is formed into cups and various other small articles.

Almost all that has been said of the cocoa tree might be repeated of the date tree, making an allowance for the specific differences of the two: and with respect to the palms in general, Humboldt says it would not be easy to enumerate the various advantages derived from them. "They afford wine, vinegar, oil, farinaceous food, and sugar; timber also, and ropes, and mats, and paper; and," he adds, that, "no trees are so abundant in fruit, even without the aid of cultivation; and that the Franciscan monks, who live in the vicinity of palm plantations, near the banks of the Orinoco, observe that the native Indians give evidence of a fruitful palm year, by the corresponding improvement in their health and appearance."||

I shall conclude this part of the subject with a translation from the Flora Atlantica of Desfontaines, for the introduction of which no apology, I trust, is necessary. In describing the natural scenery of groves of palm, the author concludes with the following beautiful passage: "These palm-groves, being impervious to the sun's rays,

* Johnstonus de Arboribus, p. 145.

† Nouv. Dictionn. d'Hist. Nat. tom. vii. p. 297, 298. ‡ Ibid.

§ Wern. Mem. vol. v. p. 110—127.

|| Humboldt, Distrib. Géogr. Plant. p. 216—240.

afford a hospitable shade, both to man and other animals, in a region which would otherwise be intolerable from the heat. And under this natural shelter, the orange, the lemon, the pomegranate, the olive, the almond, and the vine grow in wild luxuriance; producing, notwithstanding they are so shaded, the most delicious fruit. And here, while the eyes are fed with the endless variety of flowers which deck these sylvan scenes, the ears are at the same time ravished with the melodious notes of numerous birds, which are attracted to these groves by the shade, and the cool springs, and the food which they there find."*

Section III.

Vegetables as a Source of Food.

It appears from various statements of authority, that the species of vegetables already known amount to about sixty thousand:† though there is reason to believe the actual number is above a hundred thousand:‡ and, from the general analogy of nature, we may fairly conclude that no species exists without its use in the economy of the earth. Of many indeed we witness the direct use, either for the various purposes of civilized society, or for the sustenance of animal life: but for the present let us confine our attention to the latter point in their history; and, although whatever is adapted to the sustenance of animal life in general, is indirectly adapted in a great measure to the actual condition of man, and would therefore justly come within the scope of this treatise; yet, that we may not extend the subject too far, let us consider those species only which constitute the direct food of man; subject indeed frequently to such culinary preparations as make our food not only more palatable, but also more nutritious.

Among the numerous species of vegetables which supply food to man, by far the greater proportion consists of those which may be considered upon the whole as mere luxuries; or at most, as affording an agreeable and sometimes useful variety. Of those species which afford that kind of nutritive matter which is contained in what has been emphatically called the staff of life, or bread, the number is very small; leguminous plants, and wheat, and rice, the fruit and pith and other parts of some of the palms and bananas, and such farinaceous roots as the potato, &c. comprising nearly the whole amount.

* Palmeta radiis solis impervia, umbram in regione calidissima hospitalem incolis, viatoribus, æque ac animantibus ministrant. Eorum denso sub tegmine, absque ordine crescunt aurantia, limones, punicæ, oleæ, amygdali, vites, quæ cursu geniculato sæpe truncos palmarum scandunt. Hæ omnes fructus sauvissimos, licet obumbratæ, ferunt; ibique mira florum et fructuum varietate pascuntur oculi; simulque festivis avium cantilenis, quas umbra, aqua, victus alliciunt, recreantur aures."

Desfontaines, Flora Atlantica, tom. ii. Append. p. 439.

† Conversations on Vegetable Physiology, vol. ii. p. 108.

‡ Decandolle, Théorie Elém. de la Botanique, 8vo. 1819, p. 25.

It would be unnecessary to point out more particularly the importance of some of the foregoing species, to any one at all conversant with the general mode of life of Europeans as to food: and a slight acquaintance with the history of the world is sufficient to show us, that, what wheat and potato are to Europe, rice is to a considerable portion of Asia, Africa, and America; and the products of the date and cocoa, palms, &c. to the inter-tropical countries of the whole earth. But there are some natural analogies afforded by those species, with reference to the animal kingdom, which are well worthy of observation.

In the animal kingdom all those species which serve extensively for food, as oxen and sheep and swine among quadrupeds; the turkey, the common fowl, and the duck, &c. among birds; and the salmon, cod, and herring, &c. among fish, are either naturally of a gregarious nature, or are easily kept together, by human means, in large bodies; and therefore are much better adapted to the purpose of supplying food to man, than if they were either solitary, or scattered into small groups. And so it is with respect to the vegetable species above described: they are capable of being cultivated, gregariously, as it were, with comparatively little labour and attention. Thus in our own, and other European countries, the daily labourer, after his hours of hired work for others, can cultivate his own private field of wheat or of potatoes, with very little additional expense of time or trouble. And as to the cultivation of the tropical fruits, scarcely any labour is required for that purpose: so that to the less hardy natives of those climates the assertion of the poet is strictly applicable.

"Fundit humi facilem victum justissima tellus,"

A further analogy is observable in the degree of fertility of the respective vegetables and animals. Among the animals which are destined for the food of man, the species are upon the whole prolific in proportion as they are either small in size, or inferior as to the nutritive quality of their flesh. The cow, which is a large animal, produces one usually at a birth; the sheep, very commonly two; swine, several. Poultry, which are comparatively small, are capable of rearing a numerous brood; and fish, which are of a less nutritious nature, and generally smaller than quadrupeds, are still more prolific. And, similarly, in the vegetable species which are destined for the food of man, the numerical quantity of the product in a given area is greater or less, in proportion to the individual size of the fruit produced. Dates, which are smaller than cocoa-nuts, are produced in greater number than the latter; and in a square yard of soil, a much greater number of grains of rice or wheat is produced than of roots of the potato.

Lastly, another analogy may be observed with reference to the palate. The taste of the flesh of these species, which constitute to

man the staple as it were of animal food, is acceptable to most palates. And it is neither so rich as soon to cloy the appetite on the one hand, or invite it to luxurious indulgence on the other; nor so devoid of flavour, as to deter us from taking a proper quantity. And is it not the same with respect to those vegetable species, which are among the most ordinary and most necessary articles of our food? If corn, and the potato, and the cocoa-nut, had the pungency of euphorbium, the nauseating quality of ipecacuan, the heat of pepper, or the luciousness of sugar, on the one hand, or the insipidity of powdered chalk on the other; what an undertaking would it be to satisfy the craving of hunger with any one of those vegetables!*

It will be vain to urge, in opposition to the foregoing position, that custom in particular instances renders many things tolerable, and even pleasing to the taste, which at first were disgusting; for it would be found that in such instances custom has arisen from necessity, which often brings us acquainted with strange companions; or from a depraved taste. None have ever consented voluntarily to feed on the flesh of horses, or of ravens; and *caviare* will always be *caviare* to the multitude.

Next in importance to those vegetable species which either afford the material of bread, or an equivalent for it, may be classed those which contribute partly to the *nourishment* of man, and partly to his *health* and solace. The human system certainly may be, and too often from necessity absolutely is, supported solely on the nutriment afforded by the former species: but if we view the actual state of society, we find that many vegetable species and products may now properly be classed among the necessaries of life, which for many ages remained either undiscovered, or were only locally known, or sparingly employed; of which it will be quite sufficient to mention tea,† and sugar, and the potato. The sugar cane has for such a length of time usurped the prerogative of supplying the world with sugar, that other sources have been little considered: but even in cold climates there are plants capable of affording it in considerable quantities. There is, for instance, a species of maple cultivated in North America for the sake of the sugar obtained from its sap, which is capable of returning a very great profit to its cultivator; of which the following document, copied from a note by Dr. Hunter in his edition of Evelyn's Sylva, is a sufficient proof; there being no reason to suspect any fraud.‡ It is added in the same note, that a single family,

* On many occasions, however, pungent, or aromatic substances, as garlic, mustard, and spices, added to food comparatively of little flavour, as rice, &c. make it more palatable, and more easily digestible.

† During five years, beginning with 1826, about one hundred and fifty million pounds of tea were sold at the East India House, the average annual consumption being, according to the preceding statement, thirty million pounds.

‡ "Received, Cooper's Town, April 30, 1790, of W. Cooper, sixteen pounds, for 640 pounds of (maple) sugar, made with my own hands, without any assistance, in

consisting of a man and his two sons, on the maple-sugar lands between the Delaware and Susquehanna, made 1800lbs of maple sugar in one season. The whole note, consisting of eight closely printed quarto pages, which appears to have been furnished by Dr. Rush of Pennsylvania University, is well worth the perusal.*

If we consider the subordinate wants of the animal economy, we must in reason allow that those succulent fruits and vegetables, which are abundantly produced in almost all parts of the world, are destined by Providence for an important end with reference to the food of man. The very form and arrangement of our teeth, and the structure of our stomach, show, that our system is naturally adapted to a mixed food: and although those of our teeth, which resemble the corresponding teeth of carnivorous animals, are so little developed as to make it in that respect doubtful whether nature intended us to live on flesh; yet our stomach, and the rest of our apparatus of digestion, aided moreover by culinary preparation, certainly approximate us fully as much to the carnivorous as to the herbivorous classes. It is obvious, moreover, that we have an ample array of teeth for cutting and grinding vegetable matter. This then being the case, we might antecedently expect that our natural taste would lead us to enjoy the flavour of vegetable, as well as animal food; and that nature would supply us with a variety of the one as well as of the other; for variety itself is salutary.

And on this as on every occasion, we have an opportunity of seeing how Providence not only meets all the wants of mankind, but meets them in such a way as their local situation requires. Thus wheat, which contains a more strengthening principle of nutrition than the product of the palms and arrow-root, and is therefore better calculated to support the hardier efforts of the inhabitants of temperate or cold climates, will not grow readily in inter-tropical climates;† and, reciprocally, the palms and cognate plants of inter-tropical regions cease to be productive, if cultivated much beyond the tropics.‡ And the orange, the lemon, the water-melon, the grape, and the fig, which are easily cultivated in warm climates,§

less than four weeks; besides attending to the other business of my farm, as providing fire-wood, taking care of the cattle, &c.

"Witness R. Smith." "John Nicholls."

SILVA, 3d ed. by A. Hunter, York, 1801. vol. i. p. 190.

* The tree commonly called the sycamore, which is really a species of maple, yields a sweet sap, which has occasionally been used to supply the place of malt in brewing. Ib. p. 200.

† Desfontaines, Flora Atlantica, tom. ii. Appendix, p. 438.

‡ Wern. Mem. vol. v. p. 112.

§ An interesting fact is related in the "Conversations on Vegetable Physiology" respecting an artificial mode of ripening the fig. In hot climates the fig-tree produces two crops of fruit: and the peasants in the isles of the Archipelago, where the fig-tree abounds, bring branches of wild fig-trees in the spring, which they spread over those that are cultivated. These wild branches serve as a vehicle to a prodigious number of small insects of the genus called *cynips*, which perforate the

by the abundance of their juice, are enabled both to allay the sensation of present heat and thirst, and to repair the loss of that natural moisture of the body, which is continually passing from it in the form of either sensible or insensible perspiration. Even in the temperate climate of our own island, how many days are there, during the summer, in which such fruits are most refreshing: and to gratify the desire of that refreshment we import such species as are capable of bearing a long voyage; among which the orange is a very principal article of import: nor would it be easy to calculate the myriads of that fruit which are annually consumed in this country. But the cognate fruit, the lemon, at the same time that, on account of the grateful and aromatic flavour of its juice, it is occasionally as eagerly sought as the orange, serves a still higher purpose: for the acid contained in it has been successfully employed, as an antidote and a remedy for one of the most dreadful diseases to which mariners are subject. Sea-scurvy in fact has all but disappeared since the general adoption of this remedy*.

Section IV.

Vegetables as applicable to Medicine.

If vegetables are valuable on account of their power of affording sustenance and keeping the body in a state of health, they are also valuable on account of their power of restoring health where it has been impaired: for, however sceptical some minds may be as to the powers of medicine in general, and however ignorant even the most sagacious and experienced medicinal practitioners may be as to the precise mode in which any medical substance acts on the human constitution; yet this at least is certain, that, in by far the greater number of instances, certain symptoms which indicate a disturbed state of the system are mitigated, and finally subdued, in consequence of the exhibition, to use a technical term, of certain reputed remedies. And it is open to the observation of almost every one, that the vegetable kingdom is the most fertile source, not only of the commonest and least efficient, but of some of the most powerful medicines with which we are acquainted. Nor can we doubt, when we see similar effects resulting from the use of the same medicines in

figs in order to make a nest for their eggs; and the wound they inflict accelerates the ripening of the fruit nearly three weeks; thus leaving time for the second crop to come to maturity in due season." (Vol. ii. p. 41, 42.)

* It is probable that fresh vegetables of any kind are sufficient to prevent or to remove scurvy: for it is stated in Sauer's account of Billings's expedition, that that disease disappeared, even in so high a northern latitude as the Aleutan islands, as soon as the new vegetation sprang up in April (p. 276); and many other evidences of the same fact might be easily adduced.

individuals of very different constitutions, that the peculiar qualities of those substances, with respect to the effects they produce in the human system, were imparted to them by nature with a view to their application to those ends.

It may have happened to any one in the course of the last few years, during which intermittent fever or ague has prevailed very generally in this country, to witness the severe nature of some symptoms of that disease; paroxysms of dreadful rigour or shivering; nausea; intense headache, with delirium; paralytic affections of the limbs; and burning heat of the whole body, terminating in profuse perspiration: and whoever has witnessed such symptoms, recurring in the same individual at stated intervals, has probably seen their return at once arrested by a few doses of Peruvian bark, in the state of powder; the effect of which remedy, in subduing a violent disease, compared with the small quantity of it employed for that purpose, has been not inelegantly though playfully illustrated by that passage of the Georgics, in which the husbandman is taught to allay the occasional contests and agitations of the bees, by scattering a handful of dust among them.

> "Hi motus——atque hæc certamina tanta
> "Pulveris exigui jactu compressa quiescent."

And, if the vegetable kingdom had failed to afford any other medicinal substance than this, mankind would have still had ample cause for thankfulness.

But, even in the instances of those remedies from which nothing beyond a present or temporary alleviation is expected, the benefit usually accruing cannot easily be estimated at too high a rate: and one remedy there is, of this nature, for which mankind is indebted to the vegetable kingdom exclusively. How often has not opium lulled the most excruciating agonies of pain? how often has it not restored the balm of sleep to the almost exhausted body; or quieted those nervous agitations of the whole system, the terrors of which none perhaps can duly appreciate but those who have experienced them? There are however diseased or unnatural states of the body, in which no direct remedy can be applied, and all soothing means would not only be ineffectual, but fatal: in such states those substances, which are directly opposed in quality to opium, and irritate instead of soothing the surfaces to which they are applied, are valuable precisely on that account: they rouse the system, for instance, from a state of lethargy, which otherwise would probably terminate in death; or they stimulate the stomach to reject any substance of a poisonous nature, which may have been either intentionally or accidentally introduced into it, and they thus contribute to the preservation of life. Remedies of this character, though not exclusively belonging to the vegetable kingdom, are frequently afforded by it.

But, in enumerating the medicinal auxiliaries which mankind derive from the vegetable kingdom, let me not omit the restorative virtue of that gift of Heaven, which, though by its abuse it may intoxicate the mental faculties and undermine the general health of the body, is calculated most assuredly, when rightly used, not only to revive the drooping energies, but to rekindle the almost expiring spark of life. Survey the wretched subject of what is called *typhus*, while oppressed by those symptoms which justify the use of this restorative; when the glazed eye and squalid skin, the feeble circulation and muttering delirium, announce the near approach of death, unless the proper medicine be interposed; and then watch the beneficial effect of this divine remedy. They who have witnessed the progress of typhus fever in some of its forms, and in individuals who have lived in crowded and ill-ventilated habitations, will acknowledge that in very many instances wine alone has, humanly speaking, rescued the patient from the grave.

Nor will it be irrelevant to the general subject of this treatise to consider the natural origin of wine: by which I mean, not the mode or time of its discovery; either of which it would be as useless as vain to attempt to investigate, since this liquid was in common use at a period long antecedent to history: but by its natural origin I mean the circumstances under which it is usually produced. There is a law in nature, by which organised bodies, vegetables as well as animals, are disposed to undergo spontaneous decomposition very soon after they have ceased to live; the ultimate result of which is, a resolution into their elementary principles; in other words, they putrefy and perish. But even in this state, in which they are deprived of all their former properties, they administer to the good of man; and, under the name of manure, are known as the principal means of fertilizing the ground; from whence all his food is ultimately obtained. The circumstances, however, which accompany this change in vegetables, differ very much from those which attend the corresponding change in animals; and may be well illustrated by a reference to the process of making any common wine.

If a sufficient quantity of the juice of ripe grapes, or of any other saccharine fluid, be exposed to a moderately warm temperature, an internal movement of its particles soon begins to take place; which is technically called *fermentation*: and during the period when this is going on, the sugar of the liquor is, in part, converted into wine. If the fermentation be now arrested by the proper means, the whole mass of the liquid may be preserved in nearly the same state for a longer or shorter period, in proportion to the quantity of wine contained in it: but if, after the vinous fermentation, as it is called, has been completed, the temperature be to a certain degree increased, the wine is converted into vinegar by a continuance of the process of fermentation: and, ultimately, the acid taste and odour of the vine-

gar are lost; and the whole mass of the liquor becomes first vapid, and then putrid.

That such a process of putrefaction should take place in organised bodies after their death, might in reasoning be antecedently expected; for the purpose of administering to the growth of their successive generations in the case of vegetables;* and to prevent the indefinite accumulation of so much dead and useless matter in the case of animals: but we could not have anticipated, that, while animal matter at once passes into a state of putrefaction, vegetable matter should previously pass through two intermediate states; accompanied with products which in their nature differ both from each other, and from the source from which they were derived: both, however, as we might very reasonably expect from the known wisdom and beneficence of the Creator, of the highest importance to mankind.

From wine, to say nothing of the advantages resulting from its proper use in its common state, is derived that useful fluid called *alcohol*, or spirit of wine: among the most valuable properties of which, may be ranked its power of dissolving resin, and other vegetable principles; and of preserving organized matter from the putrefactive process. In consequence of the former power, it is employed to extract from various vegetables some of those parts in which their medicinal virtues reside; and to preserve them in a convenient form for immediate use, at any moment, under the technical name of *tinctures*. And with respect to its importance as a preservative of animal and vegetable matter, but particularly of the former, I need only point out any one of those collections of anatomical preparations contained in the museums of every medical school in Europe. But if any single instance of its application to this purpose be demanded, who can hesitate to name that astonishing proof of the genius and industry of the great English physiologist, John Hunter, the Collection preserved in the Royal College of Surgeons? on the pedestal of whose bust, placed within the walls of the museum of that college, might well be inscribed, as I believe has been often suggested, those appropriate words,

"Cujus monumentum si quæras, circumspice."

Section V.

Vegetables as applicable to the Arts, &c.

In considering the application of natural substances to the various purposes of life, it is often interesting to compare the simpli-

* "Haud igitur penitus pereunt quæcunque videntur:
Quando aliud ex alio reficit Natura, nec ullam
Rem gigni patitur, nisi morte adjutam aliena."
Lucret. I. 263—5.

city of the orginal contrivance with the complicated manipulations of the process by which, at the present day, a material, destined for a specific use, is brought into a fit state for that use. Let fine writing-paper be taken as an instance; and let us compare the history of a piece of such paper with that of the simple material on which many Oriental manuscripts are written—the mere leaf of a tree, probably some species of palm,—which after having been cut into the requisite size and form, seems to have undergone no other preparation than simple pressure; partly with the view of forcing out its natural moisture, and partly of smoothing its surface. How different the history of the paper that is daily fabricated in any of the large manufactories of this country; and how little would its origin and numerous changes of state be conjectured from its present appearance! Heaps of linen rags of every colour, when indeed that colour can be distinguished through the dirt which adheres to them, are brought from almost every quarter of Europe; each rag having probably been part of some article of dress, which as it grew viler by use, passed from a more to a less respectable possessor; till it at length became the tattered and threadbare covering of the poorest mendicant.

From such a material is the finest paper made: and, in the commencement of the process, each individual rag undergoes an examination with respect to its size, and is cut into two or more pieces according to that size. Separate heaps are then mechanically shaken together, and sifted, in order to clear them from adhering dust: they are subsequently washed, mechanically divided into small shreds, bleached, then thrown into vats of water, and there reduced to a fine pulp by the application of powerful machinery. This pulp, by very delicate yet simple means, is kept in a state of close and equable diffusion over an even surface, and is made to pass between successive pairs of smooth metallic cylinders; all of which, by pressing out the moisture of the pulp, bring its particles more closely together, and thus tend to give it the requisite degree of firmness and cohesion; the last pair being heated sufficiently to dry the paper during its passage between them.

Such are the numerous and elaborate processes, by which a heap of sordid rags is converted into the beautiful material of which we have been speaking. And if, to the accumulated processes to which each rag is submitted during its fabrication into paper, be added its previous history, as the cultivation and subsequent dressing of the flax of which it was made, the formation of the fibre of the flax into thread, the weaving of the thread into linen, and, in the majority of instances, the dying of the linen; if all these points be collectively considered, what food for a reflecting mind does not the minutest particle of the resulting paper afford!

Many plants are capable of yielding a colouring matter, which by chemical means may be readily made to combine with various

substances, as linen, woollen, silk, and leather. This property, which sometimes resides in the stem and branches, sometimes in the leaves and flowers, may be classed among those properties of plants, which, if we consider the actual state of society in all the civilized parts of the world, are productive of the greatest advantage to mankind. Hence, for instance, has arisen an art, the art of dying, which not only opens a wide field of employment to a numerous class of workmen, in every large city; but gives a degree of activity to general commerce, which cannot but surprise the mind of any one previously ignorant of the circumstance. Thus the quantity of indigo, accumulated in the extensive repositories of the East-India Company, is frequently so great as to make the occasional observer wonder that it should ever find a market: and the following statement will show how important this single substance is as an article of commerce. During the last five years, the quantity of indigo imported into London amounts to at least one hundred and twenty thousand chests; the average weight of the contents of each chest equalling 270 lbs., and the average price of each pound being five shillings. The estimated value therefore of the indigo contained in the 120,000 chests would be rather more than eight millions sterling.

If I am correct in supposing that *blue*, *red*, and *yellow*, are the colours most abundantly supplied by vegetables, it cannot fail to strike a mind of the least reflection, that these are precisely the elementary colours which a dier would have antecedently selected, in order to be enabled to practise his art to the greatest advantage; since from these three, all other colours or tints may be obtained. And with respect to black, which must practically be considered as a distinct colour, though not admitted as such theoretically, it is worthy of observation, that, although scarcely any vegetable substance yields it directly; yet, by the intervention of almost any form of iron, and this metal is in some shape or other present everywhere, it may readily be produced from a very numerous class of vegetable substances. In almost every instance where a vegetable substance has an austere and bitter taste, it will with iron give a die of a black colour. Thus the bark of the oak, and of many other trees, and that vegetable excrescence called the *gall-nut*, produce an ink by the addition of any saline form of iron.

From the earliest and least civilized times, and through every intermediate stage of society to the present period of refinement, the productions of the vegetable world have been in constant request for the most common purposes of life. The simplest dwellings not only of the uninstructed savage, but of the peasantry of many parts of modern Europe, are constructed almost entirely of wood; the simplest implements of husbandry, the plough, the spade, and the hoe, could hardly be employed without the aid of a wooden frame-work or handle: and the same observation holds good with

reference to the tools of the most necessary arts of life. How great would be the inconvenience, and how increased would be the labour of the carpenter, or the smith, or the mason, if, instead of wood, the handles of his implements were of iron! Nor are substances of vegetable origin of less importance, or less generally employed, in many of the higher arts of life. Examine the structure of a man of war—its hulk, of oak; its masts, of fir; its sails and ropes, of flax; its caulking, of tow and of tar. All is of vegetable origin from the top-mast head to the keel itself. With the exception indeed of the iron which is occasionally used in the construction, no metallic substance is necessarily employed; for the copper sheathing, though highly useful, is certainly not necessary.

It would require volumes to describe all the economical uses to which vegetables are applied. How many important trades arise from this source. How many families, now existing in opulence, originally derived their surnames from their occupation, and that occupation connected with vegetable materials; for instance, Cooper, Carpenter, Dier, Tanner, Turner, Wheeler, Weaver, Barker, Hayward, Gardener, Cartwright, Miller, Fletcher, Bowyer!

And then, to answer the various purposes to which they are to be applied, how widely do the qualities of different vegetable productions differ from each other! How well the rigid fibre and compact texture of the oak enable the bulky vessel to resist the buffeting of the waves! The ash, the beech, the fir, the yew, each has those appropriate qualities which make it individually preferable to the rest. The flexibility of the hemp and flax renders them capable of being woven and formed into sails and cordage; and, exposed as the sails and rigging are to the vicissitudes of the weather, how well are they protected by being covered over with tar, itself of vegetable origin!

Some woods very readily split with that regularity of surface which we observe in common laths; and of the utility of that kind of material in almost every kind of building no one can well be ignorant. Other woods, as the willow, very readily bend, with a considerable degree of elasticity, in every direction; and hence are of value in the fabrication of what is known under the general name of wicker-work.*

In this department, again, though not to the same extent as in the case of some of the metals, is seen the effect of human labour in advancing the value of the original material. Compare, for in-

* The art of making wicker-work is often successfully cultivated at a very early period of civilization. Thus, in the neighbourhood of California, some of Captain Beechey's officers were supplied with "water brought to them in baskets, which the Indians weave so close, that, when wet, they become excellent substitutes for bowls." (Beechey's Voyage, p. 385.) And we know that, not long after the conquest of Britain by Cæsar, the ornamental wicker-work of the natives was highly prized at Rome.

stance, the mercantile value of a piece of fine lace, with the original value of the material of which it is made.

There are many plants, which, though they neither produce fruit of any value nor are capable of being applied to any of the common purposes of the arts, are yet of the highest value as a natural defence to cultivated lands against the incursions of cattle; and sometimes even against the attacks of disciplined troops.

The quickset of our common hedges is an instance of the former application; and of its utility in this country no one can doubt, unless he happen to live exclusively in those districts, as in certain parts of the Cotswold and similar ranges of hills, where stone supplies a more ready material for a fence. Of the extent of its application, it would not be easy to make a correct estimate: but, when we consider how many public roads, and how many private enclosures are bounded by a fence of quickset, it becomes probable that the linear extent of hedges of this kind is, in England alone, equal to many times the circumference of the whole earth. In describing one of the most important fortresses in the Deccan, Captain Seely, in his account of the temples of Ellora, states that the town, which stands about 1020 yards from the fort, is surrounded by a hedge of prickly pear, nearly eighteen feet high, and thick in proportion. This natural defence round towns and villages on the western side of India is very common; and it offers to a predatory body of horse or foot a formidable barrier: for the sharp and long thorns, which project from the stem and leaf, not only act as an immediate defence; but, if broken off, they exude a liquid which often produces severe inflammation.*

In a part of Normandy, lying between Caen and Falaise, is a district called "Le Bocage" (*petit bois*), which "derives its name from the high and bushy hedges with which it abounds; and which are designed to afford shelter from the stormy winds of the Atlantic. There are but few trees in those parts; but the hedges, being from eight to ten feet in height, are sufficient to protect the crops from the boisterous sea-breezes: and they thence bear the name of *brise-vent*."†

The last point in the history of vegetables which I propose to consider is their application as fuel; and many nations entirely derive their supply of fuel, for culinary and other domestic purposes, from the vegetable kingdom alone: and even where such a supply is in a great measure needless, on account of the abundance of coal, yet, for many purposes, various forms of wood, either in a recent or in a charred state, are preferred, on account of the injurious effects arising from the sulphur with which coal is usually contaminated; in the heating of bakers' ovens, for instance, in the drying of malt, and in numerous processes of the arts. Around the shores

* P. 522.

† Conversations on Vegetable Physiology, vol. ii. p. 232.

of the Arctic Ocean, where scarcely any traces of native vegetation are observable, the inhabitants are amply supplied by drift-wood (Sauer's account of Billings's Expedition, p. 104—259). And Captain Beechey says, that drift-wood is to the Esquimaux what forests are to us; being in such abundance and variety, that the inhabitants have the choice of several sorts of trees. All this drift-wood about the mouths of rivers, on the north coast of America, appears to be brought down by those rivers from the interior of America: but from the occurrence of many floating trees to the southward of Kamchatka, and from other circumstances, it is probable that much of the drift-wood, found at a distance from the mouths of rivers, comes very far from the southward. (p. 575—580).

Nor does the benefit, arising from vegetable forms of fuel, terminate with their consumption. The residuary ashes are useful, as a manure for the land, on account of the alkaline matter which they contain: and that alkaline matter is also to many a poor peasant a substitute for soap; the lixivium, or ley, which may be obtained by filtering water through the ashes, owing its detergent quality to the alkali which it has dissolved in its passage. In those parts of the world indeed, as in North America, for instance, where it is requisite to clear the land of wood, for the purpose of bringing it into cultivation, the ashes of the forests, which are necessarily burned for this purpose, afford an enormous quantity of alkaline residuum; and this is the source of much of that alkali of commerce, which, from having been obtained by evaporation of its solution in iron pans or pots, is commonly known under the name of *potash*.

That other alkali of commerce, called *soda*, is derived from a similar, though indeed a much more humble source; for, in this case, the alkali does not result from the combustion of stately and aboriginal forests, but from the combustion of heaps of sea-weed; which, in various parts of the coast of Europe, has been collected from the surfaces of the adjoining rocks.*

* In some instances loose stones are intentionally placed on the sea-beach for the purpose of affording a substratum for the growth of various sea-plants, which attach themselves to the stones so placed.

CHAPTER IX.

ADAPTATION OF ANIMALS TO THE PHYSICAL CONDITION OF MAN.

Section I.

General Observations on the Animal Kingdom.

The same remark may be made with regard to the general utility of animals, which has been made in the case of vegetables: for we have sufficient reason for believing, that, among the myriads of species of animals which exist upon the face of the earth, there is not one which does not act an important part in the economy of nature.* And yet, if it be correctly stated that out of about a hundred thousand species of animals, the number supposed to have been hitherto discovered, eighty thousand are of the class of insects;† it will be evident that the mass of mankind is ignorant of the very existence of nearly four fifths of the whole animal kingdom: for, with the exception of the fly, the bee, the wasp, the ant, and perhaps ten or twelve more species, few but professed naturalists are acquainted with the specific differences of this class of animals; so small are they in size, and so apparently insignificant to a common observer. But, if we have reason for believing that not a single animal species exists without its use in the general economy of nature, we have a certainty that there are many, the absence of which would be almost incompatible with the continuance of the existence of the human race. If, for instance, the duties of the shepherd and herdsman could no longer be exercised, in consequence of the extinction of the two species of which they have now respectively the care, into what misery would not the population of a great part of the world be plunged, cut off at once from some of the most substantial forms of animal food, and the most general and effectual sources of clothing!

And, if we consider the subject in another point of view, how fitly are the natures of these species, from the individuals of which such immense advantage accrues to man, accommodated to that end! If, for instance, the sheep and the ox were carnivorous, instead of herbivorous, how could the species be preserved: or, supposing for a moment that a sufficient quantity of animal food could be procured for

* It is the opinion of Mr. Scoresby, (Account of the Arctic Regions, vol. i. p. 179, 180,) that the olive-green colour of the water, observable in many parts of the Greenland sea, is owing to the presence of numberless quantities of very small medusæ and other minute animals. "These small animals," he says, "apparently afford nourishment to the sepiæ, actiniæ, and other mollusca which constitute the food of the whale: thus producing a dependant chain of animal life, one particular link of which being destroyed, the whole must necessarily perish.

† The number is probably greater.

them, under that supposition how could it be conveniently distributed to the flocks and herds scattered over a thousand hills; which now, without any consequent trouble to the shepherd or the herdsman, leisurely crop the grass, as they slowly traverse the surface from their morning to their evening range of pasture.

Let us suppose, again, that the horse were to become extinct. In that event how greatly would be in a moment altered the condition of the whole civilized world! for by what other means could there be kept up that general communication, between distant parts of the same empire, the rapidity and facility of which contribute at the same time to national prosperity, and to individual wealth and comfort; since that recent invention, the steam carriage, though capable of supplying the place of horses along the course of regular roads, would be inapplicable in most other situations? Consider, again, the position of contending armies, whose fate often is determined by the evolutions of united squadrons of this noblest of all the inferior animals; and sometimes even by the speed of the individual charger whose rider conveys the *command* which is to determine those evolutions: or, to descend into less important though not less interesting scenes of domestic life, let us imagine, what we may perhaps have witnessed, the ecstacy of an afflicted parent, who has been enabled by the speed of this all but friend of man to reach the couch, and to receive the dying embraces of a beloved child; or to obtain those means of human aid, which haply may have averted the stroke of impending death.

But in this, as in many similar instances, we can at once perceive (what we may always in reasoning presume) that an alteration in the constitution of any department of nature would be incompatible with that harmony of the whole, the existence of which is evident to all those who are capable of observing and interrogating philosophically the phenomena of creation. And if it should be said that some species of animals have actually become extinct, and others are gradually becoming more and more rare; yet, in such instances, we shall find the fact to be either the result of a providential adjustment, if the expression may be permitted; or, of the original rarity of the species themselves, as in the case of that uncouth bird the dodo;* or, as might

* It is not without reason that the epithet *uncouth* has been applied to the dodo; for two distinguised naturalists, in their day, maintained for many years that such a form had never existed, but in the imagination of the painter. One of these individuals however at length had an opportunity of inspecting the well-known specimen of the head of the dodo, which is preserved in the Ashmolean Museum at Oxford; and was then convinced that such a bird had existed. But so far was he from producing the same conviction in the mind of his friend, by the description of the specimen, that he incurred the charge of an intentional deception; and the result was, that an interminable feud arose between them: for though they were attached to the same institution, and lived within its walls, (not indeed without other companions, or absolutely under the same roof, as their prototypes in the Eddystone light-house,) they never again spoke to each other.

possibly happen, with respect to that still more remarkable animal of New Holland, the ornithorhynchus paradoxus: in each of which instances the locality of the species appears to have been always extremely limited.

On the other hand there are species of animals, which, though so minute, and so far removed from common observation, as to be scarcely known to mankind at large, much less employed for any useful purpose, would yet be productive of great inconvenience were they permitted to increase indefinitely: and hence, although they may perhaps previously accomplish some important end in the scheme of nature, they are destined to be the food of other animals, which, being much larger than themselves, necessarily consume them in great quantity. There is hardly a bird, or a reptile, or a fish, the contents of whose stomach would not bear witness to the truth of the assertion just made: and even among quadrupeds there are many species, as the mole, the hedgehog, the manis, and the ant-eater, which, from the nature of their food, are grouped into a distinct family, called *insectivorous*.

Section II.

Geographical Distribution of Animals.

Among the strongest evidences of an intentional adaptation of the external world to the physical condition of man, may be classed the geographical distribution of animals, taken in connexion with certain points in their general history. Thus the elephant, which lives exclusively on vegetable food, is found naturally in those climates only, where vegetation is so luxuriantly abundant as easily to meet the large supply, which numerous individuals of such enormous bulk require: and then the tractability and docility of the animal are such, that its amazing strength may be easily directed to forward the purposes of man; and often is so directed, in the conduct of military operations, as well as on various ordinary occasions: and lastly, the increase of the species advances slowly; for, in by far the greater number of instances, only one individual is produced at a birth. Now had the elephant been equally adapted to colder climates, where vegetation is comparatively scant, the difficulty of supporting the individual animals in such climates would have diminished the value of the species: or, were elephants as intractable and indocile, as they are the reverse, what destruction would they not be continually dealing around them; witness the scene which took place a few years since in a public menagerie of London; where a company of musketeers was introduced, in order to subdue a single individual of this species, which had become infuriated from accidental circumstances! Or, lastly, had the elephant been as prolific as the swine, (and it should

be observed that they are branches of the same natural order,) how could the increased numbers of individuals have been maintained, in the case of a species which is not naturally capable of emigrating to a different climate?

Section III.

The Camel.

Of all animals, the camel perhaps is most exactly adapted both to those peculiar regions of the earth in which it is principally, if not exclusively, found; and to those purposes for which it is usually employed by man: to whose wants indeed it is so completely accommodated, and apparently so incapable of existing without his superintendence, that while on the one hand we find the camel described in the earliest records of history, and in every subsequent period, as in a state of subjugation to man, and employed for precisely the same purposes as at the present day; on the other hand, it does not appear that the species has ever existed in a wild or independent state.

With scarcely any natural means of defence, and nearly useless in the scheme of creation, (as far as we can judge,) unless as the slave of man, it forms a remarkable parallel to the sheep, the ox, and other of the ruminating species; which are also rarely, if ever, found, but under the protection of man, and to that protection alone are indebted, indeed, for their existence as a distinct species. Let us compare then the form, and structure, and moral qualities of the camel, with the local character of the regions in which it is principally found; and with the nature of the services exacted of it by man.

The sandy deserts of Arabia are the classical country of the camel; but it is also extensively employed in various other parts of Asia, and in the north of Africa: and the constant communication that exists between the tribes which border on the intervening sea of sand, could only be maintained by an animal possessing such qualities as characterise the camel—"the ship of the desert," as it has emphatically been called. Laden with the various kinds of merchandise which are the object of commerce in that region of the world, and of which a part often passes from the most easterly countries of Asia to the extreme limits of western Europe, and from thence even across the Atlantic to America, this extraordinary animal pursues its steady course over burning sands during many successive weeks. And not only is it satisfied with the scanty herbage which it gathers by the way; but often passes many days without meeting with a single spring of water in which to slake its thirst.

In explanation of its fitness as a beast of burden, for such desert tracts of sand, its feet and its stomach are the points in its structure

which are principally calculated to arrest our attention: and its feet are not less remarkably accommodated to the road over which it travels, than is the structure of its stomach to the drought of the region through which that road passes. The foot of the camel, in fact, is so formed that the animal would be incapable of travelling, with any ease or steadiness, over either a rough or a stony surface; and equally incapable is it of travelling for any long continuance over moist ground, in consequence of the inflammation produced in its limbs from the effect of moisture. It is observed, by Cuvier, that these circumstances in its physical history, and not the incapability of bearing a colder temperature, account for the fact, that, while the sheep, the ox, the dog, the horse, and some other species, have accompanied the migrations of man, from his aboriginal seat in central Asia to every habitable part of the globe, the camel still adheres to the desert.

And now observe how its interior structure meets the difficulty of region, where water is rarely found. As in the case of all other animals which ruminate or chew the cud, the stomach of the camel consists of several different compartments; of which one is divided into numerous distinct cells, capable of collectively containing such a quantity of water, as is sufficient for the ordinary comsumption of the animal during many days. And, as opportunities occur, the camel instinctively replenishes this reservoir; and is thus enabled to sustain a degree of external drought, which would be destructive to all other animals but such as have a similar structure: nor is any other animal of the old world known to possess this peculiar structure. But we pass to the inhabited regions of the Andes in the new world, we there meet with several species of animals, as the lama, the vigogna, and the alpaca, which, though much smaller than the camel, correspond generally in their anatomy with that animal, and particularly with reference to the structure of the stomach: they resemble also the camel in docility; and, to complete the parallel, they were employed by the aboriginal inhabitants in the new world for the same purposes as the camel in the old.

Of the two species of camel, the Bactrian and Arabian, the latter is that with the history of which we are best acquainted; and though there is reason to believe, that, whatever is said of the qualities of the one might with truth be affirmed of the other also, on the present occasion whatever is said, is referable to the Arabian species.* The camel, then, not only consumes less food than the horse, but can sus-

* The Bactrian species, which has two bosses on its back, is more peculiar to Tartary and northern Asia. The Arabian, which has only one boss, is not confined to the country from which it is named, but is the same species with that which prevails in northern Africa. As in the case of all domesticated animals the varieties of these two species are numerous: and it is a variety of the Arabian species, of a small height, to which the ancients give the name of *dromedary*, from its employment as a *courier*: but in the magnificent work of St. Hilaire and Cuvier, (Hist. Nat. de Mammifères,) the term *dromedary* is adopted, in a specific sense, for all the varieties of the Arabian camel.

more fatigue. A large camel is capable of carrying from seven to twelve hundred weight, and travelling with that weight on its back, at the rate of above ten leagues in each day. The small courier camel, carrying no weight, will travel thirty leagues in each day, provided the ground be dry and level. Individuals of each variety will subsist for eight or ten successive days on dry thorny plants; but after this period require more nutritious food, which is usually supplied in the form of dates and various artificial preparations: though, if not so supplied, the camel will patiently continue its course, till nearly the whole of the fat, of which the boss on its back consists, is absorbed; whereby that protuberance becomes, as it were, obliterated.

The camel is equally patient of thirst as of hunger: and this happens, no doubt, in consequence of the supply of fluid which it is capable of obtaining from the peculiar reservoir contained in its stomach. It possesses moreover a power and delicacy in the sense of smell, (to that sense at least such a power is most naturally referable,) by which, after having thirsted for seven or eight days, it perceives the existence of water at a very considerable distance: and it manifests this power by running directly to the point where the water exists. It is obvious that this faculty is exerted as much to the benefit of their drivers, and the whole suite of the caravan, as of the camels themselves.

Such are some of the leading advantages derived to man from the physical structure and powers of this animal: nor are those advantages of slight moment which are derived from its docile and patient disposition. It is no slight advantage, for instance, considering the great height of the animal, which usually exceeds six or seven feet, that the camel is easily taught to bend down its body on its limbs, in order to be laden: and, indeed, if the weight to be placed on its back be previously so distributed, as to be balanced on an intervening yoke of a convenient form, it will spontaneously direct its neck under the yoke, and afterwards transfer the weight to its back. St. Hilaire and Cuvier, from whom the substance of much of the preceding account is taken, assert, that, if after having laid down and received the intended freight, the camel should find it inconveniently heavy, it will not rise till a part has been taken off; and that, when fatigued by long travel, it will proceed more readily and easily if the driver sing some familiar tune. This however is a quality not peculiar to the camel.

Considered only thus far in its history, the camel easily stands pre-emiment, as the most useful, among all the species of ruminating animals, in the bodily or mechanical services which it renders to man: it is almost indeed the rival of the horse, even when compared in a general point of view; but more than its rival in its particular arena, the desert. The reindeer assists the individual wants of the Laplander by conveying his sledge over the frozen surface of the

snow: and the ox, on a more enlarged scale of labour, is employed in some countries in ploughing, or in the draught of heavy weights: but the camel was from time immemorial, up to a comparatively recent period, almost the sole intermedium of the principal part of the commerce of the whole world. Thus the spices and other rich merchandise of the East, being brought to the confines of Arabia, were conveyed on the backs of camels across the desert, and thence finding their way to the trading cities of Phenicia, while they yet flourished—and subsequently, after their destruction or decay, to Alexandria—they were distributed over the continent of Europe; enriching whole nations by the profits of the mere transfer: for thus Venice became not only the mistress of the Adriatic and Mediterranean, but in a measure the arbitress of the whole world—

"And such she was;—her daughters had their dowers
From spoils of nations, and the exhaustless East
Pour'd in her lap all gems in sparkling showers.
In purple was she robed, and of her feast
Monarchs partook, and deem'd their dignity increased."*

And when, in consequence of the discovery of the Cape of Good Hope, Alexandria ceased to be the main emporium of India and Europe, Venice declined in its riches and power; and the Portuguese, the Dutch, and lastly the English, acquired the political influence which Venice had lost: so true is the observation of Sir William Temple, that whatever nation is in possession of the commerce of India must necessarily have a preponderating influence in the affairs of the whole world.†

But, although the route by the Cape has in a great measure superseded that by Alexandria, the commercial intercourse carried on by means of the camel between opposite confines of the African and Asiatic deserts is still sufficiently extensive to make the importance of that animal very considerable: so that even now, as ages and ages since, the riches of an individual are estimated by the number of camels he may possess: and he still uses his camels either in war, or for the transport of merchandise, or for the purpose of selling them.‡

* Childe Harold, Canto IV. Stanza 2.

† For an account of the traffic between India and Europe, see Niebuhr, Descript. de l'Arabie, p. 246, &c.

‡ It cannot be considered an irrelevant, and certainly not in itself an uninteresting digression, here to observe, that there was a period in the commercial history of England, within the last century even, when the horse served the purpose in this island, which the camel serves in Arabia and other parts of the world: and a distinct trade then existed, that of the *packer;* the occupation of which was to make up bales of goods in a form convenient for carriage on the back of the *pack-horse;* and the trace of that mode of conveyance is still to be recognised in the *sign* of many inns in those parts of England where that mode of conveyance was prevalent. The same mode of conveyance is still very extensively employed in the north-eastern parts of the Russian dominions.

But it would be found, upon pursuing the history of the camel, that, while under the point of view which has been just considered, this animal contributes more largely to the advantages of mankind than any other species of the ruminating order, it scarcely is inferior to any one of those species with respect to other advantages on account of which they are principally valuable. Thus the Arab obtains from the camel not only milk, and cheese, and butter, but he ordinarily also eats its flesh, and fabricates its hair into clothing of various kinds. The very refuse indeed of the digested food of the animal is the principal fuel of the desert; and from the smoke of this fuel is obtained the well-known substance called *sal ammoniac*, which is very extensively employed in the arts; and of which indeed, formerly, the greater part met with in commerce was obtained from this source alone, as may be implied from its very name.*

Section IV.

Domestication of Animals.

Nature has implanted a disposition in almost all animals to be domesticated by man; and also a capability of becoming adapted to the various climates into which they accompany him; and this disposition and adaptation necessarily extend the utility of these animals. There is, moreover, a consequent effect of domestication which is obvious to the commonest observer; and which extends still further the benefits arising from the practice. In a state of nature, almost all the individuals of the same species of animals have, at any given period of their life, so close a resemblance to each other in form, size, and colour, that it is difficult to distinguish them at a little distance: but whenever any species has been long domesticated, or subjugated to the dominion of man, we usually find a proportional variety in those points. In proof of the foregoing assertion it will be sufficient to make a comparison between wild and tame rabbits; or between the domestic and wild cat; and to refer to the differences observable in all those animals which are constantly under the care of man, as the horse, the dog, and the ox.

The alteration which is produced in such cases, and which depends partly on climate and food and general regimen, but still more on the intermixture of the breed, is in many instances of the highest utility to man. Suppose for a moment that, in the case of the horse, any one of the existing varieties, the dray-horse for instance, or the Shetland poney, were from henceforth to determine the permanent character of the species; and observe what would

* Ammon, an ancient name of that part of the African desert situate to the west of Egypt, supplied formerly much of the sal ammoniac of commerce.

be the consequence. What a waste of power, and what an inconvenient increase of trouble and expense, both with respect to stable-room and food, would there be in using the dray-horse, where the Shetland pony would be sufficient; and, on the other hand, how ill would the Shetland pony supply the place of the dray-horse, where enormous weights were to be set in motion!

Again, in the case of the dog, were all other varieties of this most useful animal to be annihilated, and only one form to prevail, its value would be proportionally lessened. If no variety of the dog existed but the small spaniel or the terrier, the miserable inhabitant of the north could no longer travel over his native tracts of frozen snow: nor could the victim of Alpine frost in Switzerland be hereafter rescued from a premature death, as he often now is, by the sagacity and strength of the mastiffs of that region. And, in another element, how many a life, which must have been otherwise lost, has been saved from a watery grave by the joint sagacity and powerful strength of the Newfoundland dog! What would the shepherd do without the assistance which he now derives from his faithful companion? Instead of that compact phalanx which we have often seen advancing over the distant downs, under the direction of the shepherd's dog; and from time to time, in obedience to its intelligent commander, still altering its direction in advancing, as steadily as a ship in sail obeys the helm; we should see a confused and scattered multitude, which all the shepherd's skill and activity could hardly restore to order.

Nor let me be accused of inhumanity if I here instance the assistance which is given to man by those varieties of the dog which are principally used in the chace. Those feelings, which would spare the inferior animals unnecessary pain, are ever to be respected in others and cherished in ourselves; as those feelings which delight in cruelty are to be abhorred: but undoubtedly the desire of inflicting pain is not the incentive to the pleasures of the chace; and therefore, with reference to himself, the hunter is free from the charge of cruelty. With respect to the animal which is the object of the chace, the charge of cruelty is reasonably obviated by this highly probable consideration, that man can hardly inflict on the weaker animals a more cruel death than that, to which they are obnoxious by the very law of nature: for, ultimately, they will almost necessarily be hunted and destroyed by beasts of prey; or, if you suppose them to die either of disease or of old age, what misery must they not undergo in enduring this latter period of their life! In fact, unless in the case of acute disease, the occurrence of which in wild animals there is reason to think is extremely rare, they must, through mere helplessness, perish by hunger.

An ethical discussion is to be avoided on the present occasion; and I shall only therefore observe, that, with respect to the infliction of pain on the inferior animals, in the particular case now under

consideration, the grand question is the consequent effect on our own moral feelings.* If we are conscious that we are inflicting pain, we shall do right to abstain from what otherwise would be an innocent amusement; for such abstinence will be a legitimate extension of the scriptural precept, "A righteous man regardeth the life of his beast:" and if, by neglecting the suggestions of our original feelings, we have blunted the edge of the moral sense, doubtless we are culpable in a high degree. And this probably was the case in the gladiatorial exhibitions of antiquity; and is equally the case in the disgusting exhibitions of the bull-fight in Spain, and the more vulgar and not less disgusting spectacle of pugilistic engagements, or baiting of the bull, in our own country. But, omitting such palpably indefensible sports, it doubtless may be affirmed as a general truth that the amusements of hunting or of fishing are not accompanied by any consciousness of a wanton infliction of pain. And, although the occasionally concomitant habits of such sports may eventually blunt the benevolent feelings of our nature, we have not the least evidence that there is a necessary tendency in those amusements to produce that lamentable effect. There then remains, in support of the propriety of such amusements, the argument from the healthiness of the stimulus which they communicate to the mind as well as to the body; thus invigorating both: while they act as a present recreation, which in some shape or other is required by all. But if the pursuit of smaller and weaker animals should appear objectionable to any one, there still remain, in other countries at least if not in this, the wolf, the wild boar, and the tiger: and in subduing these, to which no one will probably object, the dog lends most effectual assistance to man. He is indeed of all animals the most undaunted and courageous. Mr. Burchell, who during his long residence in southern Africa had frequent opportunities of witnessing the character of this faithful guardian of man, has asserted to the author of this treatise, that he has, again and again, seen the fiercest and strongest animals shrink from the defiance of the dog; but he never saw the dog shrink from the defiance of any other animal.†

* The same observation is applicable to philosophical experiments on living animals; respecting experiments of which nature Shakspeare justly observes,

> . . . . "Your highness
> Shall from this practice but make hard your heart."
> CYMBEL. Act I. Sc. 6.

† Linnæus, in enumerating the characters of the lion, makes, by implication, a somewhat similar observation with respect to the dog. "Leo esuriens prædatur equis et aliis majoribus animalibus;—*canibus coercetur.*" (Linn. System. Gmelin. tom. i. p. 76.)

Section V.

Animals as a Source of Food for Man.

Although the inhabitants of very warm climates live principally and often entirely on vegetables; in the colder climates animal food usually makes a part of the daily sustenance of all who are not oppressed by poverty: and nature has not only provided amply for this want, but has afforded the easiest means of supplying it. The disposition of those animals, which afford the great bulk of the supply that is required, as the sheep, the ox, and the swine, is such, that they are not only disposed to live gregariously, but are readily brought under obedience, so as to be inoffensive either to the person or property of man: and their docility in this respect is particularly worthy of our attention, because, from the observations of M. Frederic Cuvier, (Mém. du Mus. tom. xiii. p. 419, 420,) it appears that herbivorous animals are not, as is generally supposed, naturally more mild and tractable than the carnivorous; in fact they are by nature less mild and tractable.

The flesh of all those species, which have been above-mentioned, is, generally speaking, acceptable to the human palate; and is in a great measure necessary to the support of those who are habitually exposed to great exertions and fatigue: but there are many occasions on which such food could not with any convenience be obtained, even by those to whom the expense is not a matter of any consideration. In situations for instance which are far removed from any town, there are very few, with the exception of the possessors of extensive landed property, who can be conveniently supplied with animal food from their own flocks and herds: and in the case of the crews of ships, which are accustomed to make long voyages, it would be utterly impossible to find room in any vessel for such a number of live animals, and still less for the food which those animals would require, as would be competent to supply the daily consumption of all on board. But in all these instances the difficulty is obviated by the preservative quality of common salt: for we know that, by the aid of salted provisions, guarded by the regular use of vegetable acids, a ship's crew may be maintained in good health for an indefinite length of time.

And then, with reference to the general question, there are almost all the herbivorous species of birds, together with the auxiliary supply of their eggs; and those numerous species both of river and of sea fish, which contribute very largely to the support of the human race, not solely by affording food, but by affording a lucrative employment to the fisherman. I omit the consideration of the turtle, the lobster, the prawn, the oyster, and a few other species; because the aggregate consumption of such kind of food is com-

paratively small; and those animals, as articles of food, may be considered rather as luxuries than necessaries.

Of the animals which supply us with food, the flesh or muscular fibre is that part which is most acceptable to the palate: and it is worthy of consideration that the flesh of those animals, of whose living services we stand hourly in need, as the horse and the dog, are so unpalatable that we are not tempted to eat them unless in cases of dreadful necessity. Many individuals however, through poverty, are content, and some by peculiarity of taste are inclined, to feed on the lungs or liver, or other of the viscera of animals. And modern researches and experiments have taught us that even the bones may be rendered digestible, either by the effect of long boiling under a high degree of artificial pressure, as in the apparatus called *Papin's Digester*, or in consequence of the removal of their earthly basis by means of any convenient acid; and we have also learned, from similar sources, that common saw-dust, by certain chemical processes, may be made nutritious: but we may fairly argue, from the provisional care of nature, that mankind will never be generally reduced to such circuitous means of obtaining their necessary food. In the mean time we may console ourselves with the reflection, that in the event of any temporary or local difficulty, we may find a supply of food where antecedently to the researches above-mentioned we should never have dreamed of looking for it. Vitruvius mentions, in speaking of the construction of garden walks, that the fragments of charcoal, which were a common substratum of such walks, had occasionally afforded a most important magazine of fuel in a protracted siege: and in such an emergency the bones of animals might continue a supply of food, after the flesh had been eaten.

Sect. VI.

Manufacture of Sal Ammoniac.

Even in the present abundance of animal food the refuse is not wasted; and all that is thrown aside, as unpalatable or indigestible, is subsequently collected, for the purpose of obtaining a material, very extensively employed and of considerable value in the arts, known familiarly under the name of *sal ammoniac*. Perhaps in the whole circle of the arts there is scarcely any process more interesting, if all the attendant circumstances be considered, than the fabrication of this substance: and the interest principally arises from this peculiarity in the nature of the process, that, among the numerous products which are evolved in its different stages, there is scarcely one which is not sufficiently useful to prevent the necessity of its being thrown away.

Any one, who is in the habit of walking much in the streets of London, will frequently see some half-clothed wretched individual stooping down and holding open an apron, into which he throws from time to time pieces of broken bone and other offal, which he has disengaged from the interstices of the stones that form the carriage pavement. The unsightly load thus obtained is conveyed to the sal ammoniac manufactory; and when a sufficient mass of bones has been accumulated from this and other sources, they are thrown into a cauldron of water, and are boiled for the purpose of clearing them of the grease with which they are enveloped: which grease, subsequently collected from the surface of the water on which it floats, is employed in the composition of soap.

The bones thus cleaned are thrown into large retorts, surrounded by burning fuel, and submitted to the process called *destructive distillation;* whereby, in consequence of the application of a sufficient degree of heat, the matter of the bone is resolved into its constituent elements, from which new compounds are formed. Of these, some pass off in the state of vapour or gas, while the fixed principles remain in the retort.

Among the more remarkable products which pass off are carbonic acid gas, commonly known by the name of *fixed air;* and various combinations of hydrogen and carbon, forming different kinds of inflammable air; together with water holding carbonate of ammonia (*salt of hartshorn*) in solution; and a peculiar oil. Of these products, the fixed air and inflammable air are disregarded, and suffered to escape. The oil is employed to feed lamps placed in small chambers, the sides of which become incrusted with the smoke arising from the combustion: which smoke being collected, becomes an article of sale under the name of *lamp black;* a substance of considerable importance as the basis of printing ink, &c.

It would be tedious, and uninteresting to the general reader, to describe all the intermediate steps of the process: and it is sufficient for the present purpose to state that, towards the conclusion of it, two new compounds are formed, namely muriate of ammonia and sulphate of soda: of which the sulphate of soda is separated by the process of crystallization, and is sold to the druggists under the common name of *Glauber's salt;* and the muriate of ammonia, (*sal ammoniac,*) the great object of the whole manufacture, is finally obtained in a separate state by the process called *sublimation.*

The form of the bones, submitted to destructive distillation in this process, is not altered; and the unvolatilized mass, remaining in the retorts, consists of the earthy and saline matter of these bones, blackened by the carbon which is evolved from their animal matter. Exposure to an open fire drives off this carbon, and leaves the bones still unaltered in form, but nearly blanched: and these bones, subsequently reduced to powder, and mixed with a

sufficient quantity of water to give them the requisite degree of consistence, are formed into vessels, which are employed in the process of refining gold and silver.

It was stated that, during the destructive distillation of bone, the carbonic acid and inflammable gases are suffered to escape: but of these the latter might be employed in supplying light to gas burners; and then, out of the numerous products of the complicated process which I have been describing, the carbonic acid would be the only substance not employed for some useful purpose.

Sect VII.

Animals as a Source of Clothing, &c. for Man.

The utility of many of those animals which supply us with food does not terminate in merely that adaptation of them to human wants. From the same animals we are supplied with clothing also; (but this service, indeed, they render to us in common with various other animals which are unfit for food); and, according to the different states of civilization in which mankind exists, that clothing is more or less artificially prepared. Thus while the African or Australian savage scarcely protects his body from exposure by a partial covering of leaves, or the inner bark of trees; and the Esquimaux envelopes his body in the undressed skin of the seal which he has recently killed, supplying also the separate coverings of his head and feet and hands from the same source; the poorest peasant of any civilized part of Europe derives his clothing not only from one but many different species of animals; to say nothing of those occasional parts of his dress which are obtained from the vegetable and mineral kingdom. The ox, the dog, the sheep, the beaver or the rabbit, and the silk-worm, in almost every instance contribute their direct contingent to the apparel of the humblest individual of Europe, who is not absolutely a mendicant: and, with reference to the dress and ornamental appendages of individuals of more elevated rank, to the animals already mentioned may be added the deer, the goat, the camel, the elephant, the ermine, and numerous other animals which supply the various and rich furs of commerce; the ostrich, and many other birds; and even the tortoise, the oyster, and the puny architect of the more beautiful species of coral.

Nor are the advantages which mankind derive from the animal kingdom, with reference to general commerce and the arts and economical purposes of life, of less importance than the foregoing. How many different substances, as leather, and parchment, and glue; and what various instruments, either for common use, or ornament or amusement, are manufactured from skin and horn, and bone and

ivory! With respect to the last-mentioned of which substances indeed, it is a highly interesting fact, that the world has not been supplied with it solely from the two still existing species of elephant, but also, and in a very large proportion, from the extinct and fossil species. Under the name of *licorne fossile*, the tusks of the extinct species have for ages been an object of commerce in the Russian dominions: and M. Pallas describes the abundance of these fossil tusks to be such, that they are found in every direction throughout the greater part of north-eastern Russia.

If we only consider the amount of the consumption of wax and honey, of what importance is not that little insect the bee: and the same observation may be made with reference to the silk-worm and the cochineal!

Lastly, for it is necessary to bring the present subject to a close, what immense advantages accrue to commerce and navigation from the traffic in even a very few species of fish, as the whale, the cod, the herring, and the pilchard! so great indeed are those advantages, that the question of the right of fishery on a particular coast has sometimes been the occasion of involving the most powerful nations in expensive wars: for these fisheries, at the same time that they are a source of immense riches to individuals, constitute, as it were, a nursery for the hardiest race of sailors, and thus become of the highest importance in a national point of view.

CHAPTER X.

ADAPTATION OF THE EXTERNAL WORLD TO THE EXERCISE OF THE INTELLECTUAL FACULTIES OF MAN.

Section I.

On the Rise and Progress of Human Knowledge.

In the preceding part of this treatise the physical character and condition of man were first considered; and, afterwards, the adaptation of external nature to the supply of his bodily wants. It remains for us to consider the adaptation of the various objects of the material world to the exercise of his intellectual faculties.

But, in contemplating the connexion which exists between the external world and the exercise of the mind of man, who shall attempt to describe the nature and boundaries of that yet unmeasured plain of knowledge, in which man is constantly either intellectually expatiating, or practically exerting himself? who, without wandering into

the mazes of metaphysical speculation—always amusing in the pursuit, but never, perhaps, satisfactory in the result—who shall develope the obscure steps by which science first finds access to the mind? In reflecting indeed on the state of civilized society during its earlier periods, there is nothing more wonderful in the intellectual history of mankind, than the skilful management of many processes in the arts, the true nature of which was not understood till ages and ages afterwards. Thus, although zinc was scarcely known as a distinct metal till about a century since; and, almost within the same period, one of its commonest ores, calamine, was held in so little estimation in Great Britain that it was frequently used merely as ballast for shipping, (Watson's Essays, vol. iv. p. 6.); yet that same ore was used before the time of Aristotle for the purpose of making brass, and to that purpose is principally applied at the present day. The process also of making wine was known in the earliest periods of history; although the principles on which it is produced were not well understood till a few years since.

Another remarkable fact in the history of human science, which, though frequently observed, has not yet been explained, is the occasional arrest of its progress at a point immediately bordering on discoveries which did not take place till many ages subsequently.* This may be affirmed, in a certain sense at least, with respect to glass: for this substance, though very early discovered, hardly came into general use for ordinary purposes till comparatively a very late period. But a more remarkable instance occurs with respect to the art of printing: and whoever looks at the stereotype stamps, as they may be called, which have been discovered at Herculaneum, and other places, will be disposed to allow that the embryo of the art of printing died, as it were, in the birth.†

In order that the external world may be fitted to the just exercise

* The substance of the following note, though not directly illustrative of the subject now under consideration, is not irrelevant to it; and is sufficiently curious in itself to justify its introduction to the notice of the reader.

In Dr. Thomson's Annals of Philosophy for 1817, p. 149, is an account of a paper read at the Royal Society, relative to some experiments made on torpedoes at Rochelle, in which it is stated that, where torpedoes abound, boys are in the habit of playing the following trick to those who are not in the secret. They persuade the ignorant boy to pour water in a continued stream upon the torpedo; and the consequence is, that an electrical shock is conveyed, along the stream, to the body of the boy.

Plutarch notices the same fact in almost the same terms. "It is affirmed by those," he says, "who have often made the experiment, that, in pouring water on a live torpedo, the hand of the person who is pouring the water will be sensible of a shock, which has apparently been conveyed through the water to his hand."

Ἔνιοι δὲ ἱστοροῦσι, πεῖραν αὐτῆς ἐπιπλέον λαμβάνοντες, αν ἐκπέσῃ ζῶσα (Νάρκε, the Torpedo,) κατασκεδαννύντες ὕδωρ ἄνωθεν, αἰσθάνεσθαι τοῦ πάθους ἀνατρέχοντος ἐπὶ τὴν κεῖρα, καὶ την ἁφὴν ἀμβλύνοντος, ὡς ἔοικε δια τοῦ ὕδατος τρεπομένου καὶ προπεπονθότος.

PLUT. MORALIA, Oxon. 4to, 1797, tom. iv. p. 643, 644.

† A very interesting conjectural account of the origin and progress of the arts, and of social life, occurs in the last part of the fifth book of Lucretius.

of our intellectual faculties, it is evidently necessary that its phenomena should be presented to our senses with a certain degree of regularity. This is a condition so obvious to a mind capable of reflection, that we find it inculcated, almost in the same terms, by two writers of the most opposite views as to the causes of those phenomena. Thus Lucretius asserts, that the sun and moon, by the constant returns of their light and the regularity of their course, afford to mankind an assurance that day and night, and the various seasons of the year, will recur not only in a definite order, but also for definite periods of duration.* And thus also, but in language and imagery more elevated, and a sublime acknowledgment of the cause, as well as a declaration of the fact, the author of the 19th Psalm affirms, that "the heavens declare the glory of God, and the firmament showeth his handywork. Day unto day uttereth speech, and night unto night showeth knowledge."

But it is also necessary to the just exercise of our intellectual faculties, that the senses of men in general should be similarly affected, when acted on by the same causes: for otherwise there would be no stability in our knowledge, as derived from these its most fertile sources. And though, from a peculiarity in original constitution, or from the effect of disease, the sensations of particular individuals may differ, not only in degree but in kind, from those of the world at large; the error is of no moment, since it may at once be corrected by a reference to the common sense of mankind.

If any one should too curiously object that there can be no direct proof of a similarity of impression, from the same object, on the senses of men in general; it might be answered, that neither is there any direct proof to the contrary: while we have many antecedent reasons for believing that there really is such a similarity of impression. The *structure* for instance of the several organs, of taste, smell, hearing, and sight, is essentially the same in all individuals; and the *functions* of those organs may therefore be presumed to be the same: and from the similarity of the natural expression of disgust, which peculiar odours and flavours usually excite in numerous individuals, it cannot be reasonably doubted that their respective senses are similarly affected by those agents.

If, again, any one should further object that we can have no absolutely firm ground for a reliance on the senses themselves, it might fairly be answered, that although, from the time of Pyrrho to that of Berkeley, there have been always *speculative* sceptics with respect to the testimony of the senses, there probably has never been a *practical* sceptic on that point. It is stated in the life of Pyrrho by Diogenes Laertius, that though that philosopher asserted the nonexistence of matter, and pretended therefore to universal indifference, he was sometimes overcome by his feelings, and would

* Lib. V. 971—979, and 1435—1438.

then act as other men act on such occasions; and, when reminded of the inconsequence of his conduct with reference to his doctrine, he would excuse himself by asserting, that it is difficult entirely to put off human nature, (ὡς χαλεπὸν εἴη ὁλοσχερως ἐκδῦναι ἄνθρωπον): and it must be confessed that, in this apology, he offered the best comment on the character of his doctrine. And most philosophically does Lucretius* argue, noticing the apparent modifications of form which bodies undergo, in consequence of being viewed at different distances, that, although no satisfactory reason can be given of the real cause of the illusion, it is preferable to assign a false reason, rather than, by a consequent want of reliance on our senses, to overturn those foundations of all belief, on which our safety and life depend.

We have seen, in the course of the foregoing inquiry, how extensively the various objects of the material world are applicable to the wants and conveniences of man in every stage of society; and we cannot reasonably doubt that they were created for that, as a main purpose, among others to which they are subservient. Such at least was the conclusion of one of the greatest philosophers of antiquity; though unaided by the direct light of revelation. "For what purpose," asks Cicero, "was the great fabric of the universe constructed? was it merely for the purpose of perpetuating the various species of trees and herbs, which are not endued even with sensation?—the supposition is absurd. Or was it for the exclusive use of the inferior animals?—it is not at all more probable that the Deity would have produced so magnificent a structure for the sake of beings, which, although endued with sensation, possess neither speech nor intelligence. For whom then was the world produced?—doubtless for those beings who are alone endued with reason." ("Sin quærat quispiam, cujusnam causa tantarum rerum molitio facta sit: arborumne et herbarum? quæ, quanquam sine sensu sunt, tamen a natura sustinentur; at id quidem absurdem est? An bestiarum? nihilo probabilius, Deos mutarum et nihil intelligentium causa tantum laborasse. Quorum igitur causa quis dixerit effectum esse mundum? Eorum scilicet animantium quæ ratione utuntur."†) Whether the earliest steps in the discovery of the arts of life depend on the effect of divine inspiration, of which the subject of that inspiration is unconscious—to which supposition there does not appear any reasonable objection—or whether they result from the impulse of unassisted reason; it would be fruitless to inquire: but it is interesting to contemplate the similarity of principle which seems to regulate the discoveries of the useful properties of material substances.‡ Man does not appear to possess that kind of instinct

* Lib. IV. 502—512.

† Cic. de Nat. Deor. lib. II. c. 53.

‡ The following passages, one from Vitruvius, the other from Cicero, are applicable on the present occasion. "The Deity has provided an abundant supply in every part of the world for the necessary wants of man; and has ordained that

which leads him to the selection of a specific sort of material for his nourishment or clothing, or for the construction of his habitation; but, in proportion as he feels new wants, he meditates on the means of gratifying them; and usually perceives, with a quick eye, those qualities in external bodies, which make them capable of being fitted to the end he has in view. This power of perception is peculiarly characteristic of the intellectal faculties of man: and although the inferior animals have, to a certain extent, the same power, with reference to their specific instincts, yet in them it is very limited. The nest of the same bird may be composed, in different years, of somewhat different materials, according to the latitude of her choice; but, with the exception of such a modification, she never varies from or improves upon the original plan: the comparatively unsheltered hovel of the rock, for instance, is never improved into the comfortable cottage of the swallow.

It is probably owing to the exercise of the above mentioned power of perception in the human mind, that the instruments and arts of uncivilized life, observable at all periods of history and in all parts of the world, have such a general resemblance; although, in the construction of the one, or the exercise of the other, there cannot have been any communication of knowledge. Compare, for instance, the stone arrow-heads and axes of the ancient Celtic nations, with the similar instruments of the inhabitants of those islands of the Pacific Ocean which were not discovered till the last century. The following fact, and accompanying remark, may be mentioned, in illustration of the present part of the subject. Captain Beechey, in describing a dead whale which had been wounded by an Esquimaux harpoon, having "a drag attached, made of an inflated seal skin,

that supply shall be easily attainable: whereas those things which are to be considered in the light of luxuries, as gold and precious stones, are rarely met with, and are procured with difficulty." ("Igitur divina mens, quæ proprie necessaria essent gentibus, non constituit difficilia et cara; uti sunt margaritæ, cæteraque quæ nec corpus nec natura desiderat; sed sine quibus mortalium vita non potest esse tuta, effudit ad manum parata per omnem mundum." Vitruv. Prefat. ad lib. viii.) "In vain had nature created gold and silver, and copper and iron, unless she had at the same time instructed mankind how to discover the repositories of those metals. And, again, in vain had the material been adapted to our wants, unless we understood the method of obtaining it in a separate and perfect state." ("Aurum et argentum, æs, ferrum, frustra natura divina gennisset, nisi eadem docuisset quemadmodum ad eorum venas perveniretur—materia deinde quid juvaret, nisi confectionis ejus fabricam haberemus?" Cicero de Divinat. lib. i. c. 51.) The following passage from Isaiah gives authority to the preceding opinion: "Doth the plowman plow all day, to sow? doth he open and break the clods of his ground? When he hath made plain the face thereof, doth he not cast abroad the fitches, and scatter the cummin, and cast in the principal wheat and the appointed barley and the rye in their place? For his God doth instruct him to discretion, and doth *teach* him." Ch. xxviii. 24—26. And so, when Dr. Thomson considers it as "remarkable that almost all those metals which were known to the ancients to possess malleability." (Thomson's Chemistry, sixth edit. vol. i. p. 325.) it may with propriety be observed that those are exactly the metals, without which society could not have existed.

which had no doubt worried the animal to death," adds this pertinent observation. "Thus, with knowledge just proportioned to their wants, do these untutored barbarians, with their slender boats and limited means, contrive to take the largest animal of the creation." Voyage to the Pacific, p. 270.*

It is probable, then, that there is an instinctive tendency in man to meditate on the nature and properties of those material objects and phenomena which are frequently presented to his view; and subsequently to derive from this meditation the means of applying those objects and phenomena to his wants, whether of a necessary or an artificial character. Thus astronomy was originally cultivated with most success by those who lived in a climate in which an unclouded sky prevailed; navigation, by those who lived on the borders of the ocean; and the general arts of life, by those who inhabited regions characterised by the fertility of their soil, and the abundance and variety of their mineral productions. Of these positions, ancient Egypt, Phenicia, and India are respectively instances: though it is not intended to affirm that an unclouded sky is alone sufficient to produce a tendency towards the cultivation, much less a national superiority in the science of astronomy; nor a vicinity to the sea, an excellence in nautical skill; nor, lastly, a fertile soil and abundance and variety of mineral riches, a correspondent skill in the general arts of life. In every instance it may be presumed that civilisation must have advanced sufficiently to have produced many artificial wants, before individuals feel that powerful stimulus which prompts them to take the full advantage of those resources which nature has placed within their reach. The miserable natives of New Holland, though inhabiting a country as extensive, and in parts

* The same author observes, in a short sketch of Upper California, that the natives cultivate no land, but subsist entirely "by the chase and upon the spontaneous produce of the earth; acorns, of which there is a great abundance in the country, constituting their principal vegetable food. Of these acorns they procure a supply in the proper season; and, after having baked them, they bruise them between two stones into a paste which will keep unto the following season. The paste, before it is dried, is subjected to several washings in a sieve; which process, they say, deprives it of the bitter taste common to the acorn. We cannot but remark that the great resemblance this custom bears to the method adopted by the South Sea islanders to keep their bread-fruit: nor ought we to fail to notice the manner in which Providence points out to different tribes the same wise means of preserving their food, and providing against a season of scarcity." (p. 399.) A similar reflection will naturally occur to the reader with respect to their mode of decoying deer and ducks: their plan, in the latter instance, differing very little from our own; in the former, being conducted on the principle of the stalking-horse, (p. 399, 400. See also De Bry, vol. i. pl. 25. Descript. of Florida.)

On one occasion, in alluding to the structure of the bow among uncivilized nations, Captain Beechy forcibly reminds the classical reader of a line in the first book of the Iliad: δεινη δὲ κλαγγη γένετ' αργυρέοιο βιοῖο: for, after having said that the Californians string their bows much as we do (p. 402,) he states that the Esquimaux leave the string in contact with about a foot of the wood at each end; while the Californians muffle that part with fur, in order to prevent the *report*, which would betray them, when fighting in ambush. (p. 575.)

as fertile as Europe, have afforded no indications of an approach towards that degree of civilisation which would lead them to discover and apply its resources.

But, though it would be a vain and useless speculation to inquire in what way the arts and sciences actually arose, or how it has happened that they were more or less successfully cultivated by different nations, it cannot be either uninteresting or uninstructive to compare the progress which natural science had made in Europe, at a period shortly antecedent to the Christian era, with the state in which it now exists: and such a comparison is in strict accordance with the original intention of this treatise. The materials for this comparison, which will be attempted only on a plan the most general, have been principally derived from Lucretius, and from that work of Aristotle which is entitled, Περὶ Ζώων Ἱστορίας. It should be remembered, however, that there is a broad line of distinction between the mode in which natural science was cultivated by the ancients, and that which has been adopted by the moderns. The ancients, though on many occasions as accurate observers of the obvious phenomena of nature as the moderns, were too hasty in coming to conclusions as to the character and cause of those phenomena; and hence the crude opinions and theories with which their philosophy abounded. But, if we justly consider the precept of Thales, "Know thyself," as a precept of the highest wisdom for our moral conduct, we must, on equally strong grounds, consider it as the highest prerogative of reason, or our intellectual nature, to know the actual extent of its own powers: and it is one of the glories of the philosophy of the present day, that, instead of being ashamed of its own limitations, and consequently prone to hurry into unfounded assumptions for the purpose of hiding its ignorance, it explicitly, and at once, acknowledges the point which for the present must be considered as a barrier to further progress; still however looking forward to the period when the increased accumulation of new facts shall enable it to remove that barrier.

Section II.

Opinions of Lucretius on the Constitution of Matter in general; and on the Nature of Light, Heat, Water, and Air.

In attempting to explain the constitution of the universe, and the general phenomena of nature, Lucretius assumes that matter in its primary form consists of very small and impenetrable particles, which, from their supposed incapability of further division, are called *atoms*: that, from the fortuitous concourse of these atoms, all natural bodies were originally produced; and that into these they are again resolved by those common processes which we are con-

stantly witnessing, as the death and consequent decomposition of vegetables and animals, and the wearing away of the most solid bodies by the effect and exposure to the air, or by the insensible attrition of other bodies: and, lastly, he maintains that these atoms existed from eternity, and are in their essence indestructible.

He asserts as untenable, in fair reasoning, the opinion that there is no term to the divisibility of matter; since, on that supposition, the smallest bodies would consist of an infinite number of parts: and he consequently concludes that those indivisible bodies or atoms must be perfectly solid.* He impugns, as opposed to common sense, the doctrine of Heraclitus that all things are formed from fire,† and also the doctrine of others, that all things are formed from fire or air, or water or earth;‡ or from binary combinations of them, as of air and fire, or of earth and water: and, lastly, he rejects also the doctrine of Empedocles, that all natural substances are produced from the joint union of fire, earth, air, and water.§ And Lucretius, himself supposes that the original atoms of matter may, by a mere variation in the modes of combination, produce all the objects of nature, whether animate or inanimate; illustrating his argument ingeniously by a reference to the fact, that an endless variety of words, of the most different meaning and sound, is produced by various combinations of the same letters.||

It is not necessary, on the present occasion, to comment on the obviously atheistical character of some of the opinions of Lucretius: but it may safely be affirmed that, although he strains the application of his general argument so as to support a belief in the eternity of matter, denying equally its creation and destructibility; yet the basis of his argument, if confined, as it ought to bave been, to the existing constitution of the earth, rests on a legitimate deduction from the phenomena of nature: for, certainly, there is no reason for believing that a particle of matter has either been lost or added to the earth or to the atmosphere, since their creation. And, in reasoning from the mere phenomena, Lucretius justly asks, if everything which disappears, in consequence of age and apparent decay, is actually destroyed, whence is there a renewal of animal or vegetable life? how do rivers continue to flow?¶ concluding with one of those beautiful illustrations, in which his poem abounds. "It may be said perhaps, that the showers, which sink into the earth and are lost to our sight, apparently perish: but then, from their fertilizing effects on the soil, and their subsequent incorporation with the growing seed, the harvest rises, and the vine and fig-tree flourish. Hence, moreover, animal life in general derives its support; the sportive lamb hence draws its nutriment from its full-fed mother, and wantons round the meads and woods; and hence those woods themselves

* Lucret. lib. I. passim.
† Lib. I. 636—639, and 691—700.
‡ Lib. I. 706—712.
§ Lib. I. 713—717.
|| Lib. I. 817—829.
¶ Lib. I. 226—232.

yearly resounded with the melody of their native tenants. Nor does the effect stop here: for we ourselves ultimately derive our support from the same source; and cities are eventually peopled from the nutriment produced by the very rain which we had fondly supposed to perish. But nothing really perishes; nature producing new forms of matter, from the materials of those which have apparently been destroyed."*

It would appear, from a very remarkable passage in Lucretius, that some of the philosophers of his day entertained an opinion, which he himself however opposes, that there exists a universal law of gravitation, by which all bodies tend towards the earth as the centre of the universe; that, in consequence of this law, the bodies of those animals which inhabit the opposite, or, as it were, the inferior surface of the earth, are no more capable of falling into the sky which surrounds them, than the animals inhabiting our own, or the relatively upper surface of the earth, are capable of rising into the sky which is placed above them. And, correspondently with the spherical form of the earth, which almost necessarily follows as a corollary from such an exposition of the law of gravitation, the same philosophers argued that, at the same moment when on the opposite surface it is day, with us it is night.†

Although Lucretius, when speaking in general terms of the tendency of all heavy bodies to fall towards the earth, and of the acceleration of motion and increase of force which they acquire in falling, offers such an account of the facts as we might expect from his confused doctrine of atoms, and shows his ignorance of the real character of *positive* gravity; yet of the nature of *relative* or *specific* gravity, that is, of the cause why equal bulks of different bodies are of different weights, he gives the true explanation, by asserting that the heaviest bodies contain most matter, and consequently have fewest pores.‡ That such pores exist not only in wool, and bodies of a similar texture, but even in those which are hard and compact, is proved, he affirms, by the percolation of water through the roofs of caverns; and from the transmission of the food both of animals and plants into their extreme limbs and branches.§

Lucretius considers *light* as a very subtle kind of matter, which, from its tenuity, is capable of inconceivably swift motion; the rapidity of which motion he instances in its nearly instantaneous diffusion through the whole heaven.|| With respect to the connexion of light and colour, he not only affirms that the latter cannot exist without the former; but that the particular colour observable in different bodies is not inherent in those bodies, and that in every instance it is produced by the direction, or other circumstances, under which light impinges either on them, or on the eye of the be-

* Lib. I. 251—265.
† Lib. I. 1051—1065.
‡ Lib. VI. 334—346. and lib. I. 359—370.
§ Lib. I. 347—354.
|| Lib. IV. 184—190, and 200—202.

holder: and he gives as examples the plumage of the neck of the pigeon, and of the tail of the peacock.* And thus, he adds, the countenances of the audience, and the whole interior of a theatre, closed in with coloured curtains, are tinged with the colour of those curtains.† He instances the foregoing position by a reference to the colour of the sea; which, when viewed in the mass, is blue or green; but, when converted into mere spray, is white.‡ And he argues that colour does not belong to the ultimate constituent parts of bodies, on this ground—that if coloured bodies be reduced to minute particles, the colour vanishes.§

Occasionally he employs terms which, even at the present day, correctly express the fact of the equality of the angle of *incidence* and of *reflexion*: and he graphically describes the effect of *refraction* in altering the line of direction of the rays of light.‖ But, in alluding to the phenomenon of the rainbow, he briefly states some of the circumstances under which it appears; without attempting to account for the mode in which the effect is produced.¶

Lucretius supposes *heat* to be a material substance, because it excites a specific sensation in animal bodies:** and, notwithstanding the obvious alliance between *heat* and light, which is observable in many common phenomena and operations, he conjectures, what has been most unexpectedly ascertained by the experiments of the late Dr. Herschel, that there are rays of heat emitted from the sun, which are distinct from the rays of light emitted from the same source.††

In speaking of the natural sources of heat, he observes, that it is generally produced by rapid motion; and gives as an instance of the heating and even the liquefaction of a leaden bullet, which has been projected through the air with great force and rapidity.‡‡ He also notices friction as a source of heat; instancing the fire which is produced by the mutual attrition of branches of trees.§§ In speaking of compression, as another source of heat, he not only gives the more obvious and probable illustration of lightning, *expressed* or forced out from a condensed cloud:‖‖ but, in mentioning a spring of water observed to be periodically warmer in the night, and colder in the day, he almost anticipates the views of modern chemistry respecting the different capacities of bodies for heat; when, in accounting for the fact, he supposes the heat to be forced by compression, occasioned by diminution of temperature, from the surrounding earth into the water.¶¶ His interpretation indeed of the phenomenon is not correct; but this error does not interfere with the ingenuity of the illustration, or its coincidence with modern hypothesis: and it is remarkable that,

* Lib. II. 794—808.
† Lib. IV. 70—78.
‡ Lib. II. 736—772.
§ Lib. II. 825—832.
‖ Lib. IV. 319—324, and 438—444.
¶ Lib. VI. 524—526.
** Lib. I. 299—304.
†† Lib. V. 609—612.
‡‡ Lib. VI. 176, 177, and 305—307.
§§ Lib. V. 1095—1099.
‖‖ Lib. VI. 270—275.
¶¶ Lib. VI. 861—873.

even after the lapse of twenty centuries, the real nature of heat is still questionable. We now know that, in such instances as that just mentioned, the apparent difference of temperature depends upon the relative temperature of the surrounding air; water which has been recently drawn up from the well feeling cold in the heat of summer; but warm, during a frost. The fact is, that, being really of a mean temperature throughout the year, it will be greatly beneath the temperature of the air of summer, and therefore will then appear cold; and it will be on the other hand above the temperature of the air of winter, and will therefore at that season appear warm.*

From various phenomena, as from the drying of linen, or from its becoming damp without a visible accession or exhalation of particles of moisture, Lucretius argues that *water* is capable of existing in the state of an invisible vapour.† He asserts also that its constant exhalation from the sea is proved by the corrosion of walls built near the sea-shore, and from the salt taste perceptible in our mouths while walking near the sea;‡ and that, although this exhalation takes place in a small quantity only, at any given moment and from a given surface, the aggregate quantity, which is the ultimate result, is very great; and, lastly, that in consequence of this exhalation, the sea does not increase in quantity notwithstanding the constant influx of rivers, and the rain that falls into it.§ He notices moreover and accounts for the equality of the balance, between the quantity that falls into the sea from rain and rivers, and the quantity that is evaporated from the surface of it.‖

In speaking of *atmospherical air*, Lucretius maintains that, although in its nature invisible, and to all common perception intangible, from various phenomena it may be reasonably inferred, that it is really a tangible, in other words a material, substance. "Thus," he says, "when we observe that the winds, which are evidently nothing more than currents of air, not only drive the clouds in various directions, but violently agitate the ocean; and even occasion the wreck of the largest ships, by dashing them against the rocks; or when, in the form of a hurricane, they snap asunder the stateliest oaks, and lay prostrate in their course the honours of the mountain forest; we cannot doubt that in their mode of action, as well as in the destructive character of their effects, they resemble the inundation of a rapid river; like which, they sweep before them every obstacle, or carry up the heaviest bodies into the atmosphere, in their invisible eddies, with no less ease than the eddies of a rapid stream ingulf whatever

* Aristotle, in his history of animals, mentions as a fact, without however offering any explanation of it, that during the night the water is warmer than the air; for in stating that crocodiles commonly remain on the land during the day, but in the water during the night, he adds as a reason, that during the night the water is warmer than the air, (ἀλεεινότερον γάρ ἐστι τῆς αἴθρας. Ed. Bekker. p. 37.)

† Lib. I. 306—311.

‡ Lib. IV. 219—227.

§ Lib. V. 381—394.

‖ Lib. VI. 607—630.

comes within their vortex*." He also shows, by a still more refined argument, that the air must be a material substance, because it offers resistance to falling bodies; proving this resistance by the difference in the velocity of falling bodies of different weights: for, were there no resistance in the air, he asserts, and the fact is experimentally shown in modern lectures, that unequal weights, meeting with no impediment or support, would fall with equal velocity†.

Lucretius distinctly notices the physical office of the air as a receptacle, and medium of conveyance for sound‡ and odours,§ and the various exhalations continually arising from the surface of the earth‖. But, though he is right in asserting that the skin of animals and the bark of trees are a protection against the action of the air, he is wrong in supposing them to be a protection against the *mechanical* action of that element.¶ The science of chemistry, which had not then arisen, has taught us that such external coverings are a protection against the *chemical* action of the air.

It appears probable, from the preceding statement, that in the age of Lucretius philosophers had formed some reasonable conjectures respecting the nature of light and heat; and that several of the physical phenomena of water and of atmospherical air had been accurately observed, and upon the whole correctly explained by them. And even in a subject of a much more subtle nature, the mutual attraction of the magnet and iron, the explanation of the phenomenon was attempted with a degree of ingenuity quite equal to that, which has marked the reasonings of some of the philosophers of the last and present century, on subjects of a similarly abstruse nature.

In proceeding to account for the attraction of iron by the magnet, Lucretius first describes the well-known experiment of a short chain of iron rings, the several links of which are held together merely by the force of magnetism; the attractive power of which is communicated continuously from the first to the last in the series. He then claims the particular attention of his reader to his proposed explanation of so difficult a subject, by reminding him that, in facts of this kind, many points must be laboriously investigated and established, before a rational solution can be given. Thence, assuming that from all bodies minute particles are constantly radiating, of which, those from some bodies are disposed to affect one sense; from others, another sense; and that all bodies are porous to a greater or less extent, and are severally indued with their specific qualities, affecting or being affected by different bodies differently; he argues that, from the magnet as from all other bodies, such minute and specific particles are constantly emanating; that this emanation dissipates the air from the space intermediate to the

* Lib. I. 272—295.
† Lib. II. 230—239.
‡ Lib. IV. 561—563, and 572, 573.
§ Lib. IV. 219—222, and 228—230.
‖ Lib. V. 276, 277.
¶ Lib. IV. 930—934.

magnet and iron; and that, a partial vacuum being thus formed, the ring is immediately propelled, by the air on the other side of it, towards the magnet, to which it subsequently adheres by an invisible bond of union; and so, in succession, all the other rings are impelled: the adhesion taking place by some process, as insensible as that which unites glue to wood; mortar to stone; or the colouring particles of the purple die, to wool.*

The observations of Lucretius which relate to the mineral and vegetable kingdoms are too few, and of too general a nature, to justify even a cursory comparison of them with the present state of science in those departments: and though Pliny dedicates a considerable proportion of his Natural History both to minerals and vegetables, there is nothing sufficiently systematic in his method, or approximating to the present state of science, to be of any avail for that purpose. The same remark holds good even with respect to Theophrastus, not only in the case of minerals, but of vegetables also. The ancients had a glimpse indeed of the sexual system of Linnæus, with reference to the *palms;* but show no tendency to a generalization of the observation.

Section III.

Opinions of the Ancients on the Organization and Classification of Animals.

It appears from what has been said in the preceding section, that in mineralogy and botany we scarcely find among the ancients the slightest indications of those comprehensive systems, in the construction of which the last and present centuries have been principally instrumental.

Not so in the animal kingdom. In this branch of science the true principles of classification seem to have been almost as clearly understood in the age of Aristotle, as at the present day: and, in order to enable the reader to judge of the truth of this assertion, I propose to offer a short and cursory analysis of that work of Aristotle which is entitled Περὶ Ζώων Ἱστορίας;† comparing it at the same time with similar modern works, and particularly with that of Cuvier entitled, "Le Règne Animal, distribué d'après son Organization," which was published in Paris in the year 1817, in four octavo volumes.‡

* Lib. VI. 906—1088.

† It will be convenient here to state, that the edition to which references will be made in the following pages is that of Bekker, Berlin, 1829, 8vo.

‡ A new edition of this work was published in 1829, but the preface of the first is retained without any important alteration, and indeed with scarcely any alteration at all. Nor are the alterations, or additions, which have been made in the body of the work, of such a nature as to affect the present comparison.

I shall not stop to inquire whether the work of Aristotle is to be considered as containing the result of his own observations only, or whether he has collected into one body all that had been observed by others as well as himself; which last supposition, however, is probably the true state of the case. But in order to illustrate the magnitude of such an undertaking, and the difficulties attendant on it, even in the present splendid era of philosophical discovery, I need only refer to the following acknowledgment of Cuvier, Aristotle's great rival in this department of natural science, contained in the Preface of the "Règne Animal." He there at once confesses, with reference to his own work, that it would have been utterly impossible for any insulated individual, however long his life, and however great his leisure, to complete a systematic classification of animals on the principle of conformity of structure (which, it should be observed, is Aristotle's leading principle as well as his own); that he should not even have been enabled to offer the present simple sketch, had not the advantages of his situation compensated for his want of time and talent. Surrounded as he was by so many accomplished Naturalists; deriving information from their works at the moment of their publication; and having as free access to their collections as to his own; a great part of his labour necessarily consisted, he affirms, in the application of so many and such rich materials to his present essay.

He accordingly acknowledges his obligations to Geoffroy, Levaillant, Oppel and Blainville, Lacepede, and Lamarck, in the respective departments of quadrupeds, birds, reptiles, fish, and testaceous animals; all which classes of animals are described in the two first volumes of his work. And he particularly expresses his obligations to Latreille, who furnished him with the entire third volume of the "Règne Animal," containing the arrangement of crustaceous animals (*lobsters*, &c); the arachnida (*spiders*, &c.) and insects.* Of his fourth and last volume he speaks in such brief terms as the nature of its contents requires; for, inasmuch as it only contains a compressed account of those animals whose history is very obscure, either from the minuteness of their size, or from our ignorance of their habits and modes of life, it is necessarily very short in itself, and concise in its details.†

It is clearly immaterial, on the present occasion, whether the work of Aristotle, which we are about to examine, be entirely his own, or only a systematic exposition of the opinions and knowledge of others; for, on either supposition, it is evidently a representation, on the authority of which we may fairly rely, of the general amount of knowledge accessible to the contemporaries of Aristotle, in that department of natural science: and as, with even still greater confidence, we may rely on Cuvier's work, as a similar

* Preface, p. ix. x.

† Pref. p. xi.

representation of the existing state of knowledge in the same department, I may safely refer to it as a standard of comparison with reference to the knowledge and opinions of the moderns.

In attempting to give an account of Aristotle's views, it is prudent to state that it has been collected from numerous and various notices distributed very irregularly throughout the body of his work; so that it is scarcely possible to be confident of having given the correct reference in every instance. It is prudent to make this statement, lest any of my readers should be led, in consequence of an incorrect reference, to doubt the fidelity of the representation here given, from the difficulty of meeting with the original passage. This difficulty is perhaps greater in the case of Aristotle, at least with respect to the work in question, than in the case of most other authors, in consequence of what may be called his Pindaric style of digression; which is occasionally so abrupt as to be at first view ludicrous. Thus, in comparing the kidney of the turtle with that of the ox, he suddenly illustrates his subject by observing that the viscera of the bonassus also (an animal not very like a turtle) resemble those of the ox. (Ἔχει δε καὶ ὁ βόνασος τα ἐντὸς ἅπαντα ὅμοια βοΐ. p. 45.) And, again, in the midst of a whole page descriptive of snakes, when speaking of their cloven tongue, he abruptly says that the seal (an animal not more like a snake, than the bonassus the turtle) also has a cloven tongue. (Ἔχει δε καὶ ἡ φώκη ἐσχισμένην τὴν γλωτταν. p. 48.) It may however be presumed that, in these, as in many other instances, not only of this but of many other of his works, the text has been vitiated or interpolated. Indeed some of the opinions expressed in the work are so opposed to the acknowledged physiological acuteness of its author, that they cannot be consistently admitted to have originated with him: and such, assuredly, is the solution offered in explanation of the physical phenomenon to which allusion is made in the proverb, ἀεὶ Λιβύη φέρει τι καινόν: respecting which he says "that, in consequence of the want of rain in Libya, animals of all kinds congregate wherever there is water; and that, being rendered tame by thirst, all those individuals which, though of different species, are nearly of the same size, and which go with young for nearly the same period, breed together and produce new forms."

(Πολυμορφότατα δὲ (τὰ ζῶα) ἐν τῇ Λιβύῃ—διὰ γὰρ τὴν ἀνομβρίαν μίσγεσθαι δοκεῖ ἀπαντῶντα πρὸς τὰ ὑδάτια, καὶ τὰ μὴ ὁμόφυλα, καὶ ἐκφέρειν ὧν οἱ χρόνοι οἱ τῆς κνήσεως οἱ αὐτοὶ καὶ τὰ μεγέθη μὴ πολὺ ἀπ' ἀλλήλων· πρὸς ἄλληλα δὲ πραΰνεται δια τὴν τοῦ ποτοῦ χρείαν. p. 248.)

With reference to animal life in general, Aristotle notices the gradual advances made by nature from the state of inanimate matter to that of living beings; whence there arises a difficulty in ascertaining the common boundary of the two divisions. And he then observes that, in the scale of material existence, plants immediately succeed to lifeless forms of matter; and that although among plants the degree of the living power is "various, some

being indued with a greater portion of it than others; yet, considered collectively, plants represent as it were a middle term between animals and all other bodies; appearing as indued with life, in comparison with all other forms of matter, but devoid of life in comparison with animals. The change from the vegetable to the animal nature is as gradual, as from inanimate to vegetable matter: for there are some marine productions, of which it is difficult to affirm whether they are animal or vegetable; since they permanently adhere to the spot where they are found, and cannot be separated from it without perishing; and they manifest very obscure, if any, signs of sensation. Indeed the whole class of testaceous animals can scarcely be considered as superior to plants, when compared with those animals which are indued with the power of moving from place to place."

(Οὕτω δ' ἐκ τῶν ἀψύχων εἰς τὰ ζῷα μεταβαίνει κατὰ μικρὸν ἡ φύσις, ὥστε τῇ συνεχείᾳ λανθάνειν τὸ μεθόριον αὐτῶν καὶ τὸ μέσον ποτέρων ἐστίν· μετὰ γὰρ τὸ τῶν ἀψύχων γένος τό τῶν φυτῶν πρῶτόν ἐστιν· καὶ τούτων ἕτερον πρὸς ἕτερον διαφέρει τῷ μᾶλλον δοκεῖν μετέχειν ζωῆς, ὅλον δὲ τὸ γένος πρὸς μὲν τἄλλα σώματα φαίνεται σχεδὸν ὥσπερ ἔμψυχον, πρὸς δὲ τὸ τῶν ζώων ἄψυχον. ἡ δὲ μετάβασις ἐξ αὐτων εἰς τὰ ζῷα συνεχής ἐστιν—ἔνια γάρ των ἐν τῇ θαλάττῃ διαπορήσειεν ἄν τις πότερον ζῷόν ἐστιν ἢ φυτόν· προσπέφυκε γάρ, και χωριζόμενα πολλὰ διαφθείρεται των τοιούτων—ὅλως δὲ πᾶν τὸ γένος τὸ των ὀστρακοδέρμων φυτοῖς ἔοικε πρὸς τὰ ποθευτικὰ των ζώων. καὶ περὶ αἰσθήσεως, τὰ μὲν αὐτων οὐδὲ, ἐν σημαίνεται. p. 212, 213.)

Again, if we regard the *substance* of the lower species of marine bodies, though in some instances, as in sea-nettles, it approaches to the character of flesh; in others, as in sponge, it closely resembles a vegetable matter. And, lastly, as different bodies appear to partake, in different degrees, of life itself; so do they differ with respect to the degrees of activity in the functions of life. Plants, for instance, seem to be incapable of effecting much beyond their individual nutrition, and the continuation of their species: and the same observation holds with respect to the lowest species of animals. By the addition of sensibility in different degrees, the pleasure and activity of life are increased; first in the gratification arising from mutual intercourse; and further, in the natural affection which the parent feels for its offspring, and in the care of providing food for it."

(Ἡ δὲ τοῦ σώματος ἐνίων σαρκώδης ἐστὶ φύσις, οἷον τά τε καλούμενα τήθυα καὶ τὸ των ἀκαληφων γένος· ὁ δὲ σπόγγος παντελως ἔοικε τοῖς φυτοῖς. ἀεὶ δὲ κατὰ μικραν διαφορὰν ἕτερα πρὸ ἑτέρων ἤδη φαίνεται μᾶλλον ζωὴν ἔχοντα καὶ κίνησιν· καὶ κατὰ τὰς τοῦ βίου δὲ πράξεις τὸν αὐτὸν ἔχει τρόπον. των τε γὰρ φυτων ἔργον οὐδὲν ἄλλο φαίνεται πλὴν οἷον αὐτὸ ποιῆσαι πάλιν ἕτερον, ὅσα γίνεται διὰ σπέρματος· ὁμοίως δέ καὶ των ζώων ἐνίων παρὰ τὴν γένεσιν οὐδὲν ἔστιν ἄλλο λαβεῖν ἔργον—προσούσης δ' αἰσθήσεως ἤδη, περί τε τὴν ὀχείαν διὰ τὴν ἡδονὴν διαφέρουσιν αὐτων οἱ βίοι, και περὶ τοὺς τόκους καὶ τὰς ἐκτροφὰς των τέκνων. p. 213.)

Some animals, then, merely extend their species, after the manner of plants, at stated seasons; and take no care of the individuals

produced by them. And even of those animals which provide nourishment for their offspring, the greater number exercise their care for a definite period only; that is, till their young are capable of providing for themselves: after which, they forsake or have no further communication with them. Some indeed, apparently indued with a higher degree of intelligence, enter into a social communion, and establish a kind of polity with their offspring."

(Τὰ μὲν οὖν ἁπλως, ὥσπερ φυτὰ, κατὰ τὰς ὥρας ἀποτελεῖ τὴν οἰκείαν γένεσιν· τὰ δὲ καὶ περὶ τὰς τροφὰς ἐκπονεῖται τῶν τέκνων, ὅταν δ' ἀποτελέσῃ, χωρίζονται καὶ κοινωηιάν οὐδεμίαν ἔτι ποιοῦνται· τα δὲ συνετώτερα καὶ κοίνωνοῦντα μνήμης ἐπὶ πλέον καὶ πολιτικώτερον χρῶνται τοῖς ἀπογόνοις. p. 213.)

And he makes a distinction in another part of his treatise between such animals, and those which are simply gregarious; the former being characterised by the disposition to contribute collectively to the completion of some one work; as man, the bee, the ant, &c. (πολιτικα δ' ἐστιν ὧν εν τι καὶ κοινὸν γίνεται πάντων τὸ ἔργον· ὅπερ οὐ πάντα ποιεῖ τὰ ἀγελαῖα. ἔστι δε τοιοῦτον ἄνθρωπος, μέλιττα, σφὴξ, μύρμηξ. p. 4.

With the exception of the opinion that inanimate matter graduates into life, nothing advanced by Aristotle in the foregoing observations, if considered in the light of a general statement, is contradicted or set aside by our present knowledge. For no opinion perhaps is more prevalent, among those who are capable of fairly investigating the characters of natural objects and phenomena, than that there are gradations of excellence in the various forms of matter; although the limits of distinction are often obscure. Who, for instance, that has compared the respective structures and qualities of the bodies, can doubt that the most splendid mineral indicates, humanly speaking, an infinitely less effort of creative and superintending power than the most simple vegetable? In the mineral we find a perfect similarity, or rather sameness, of character, pervading all the integrant particles of the mass; the order of their union being the result of a mere external force, which, having once brought them together, ceases to have any further effect. In the vegetable we find a most curiously arranged system of internal tubes or pores, which attract and separate the elementary principles of the soil and of the atmosphere in which the plant is placed; giving rise to structures the most wonderful, and, if we contemplate different individuals of the vegetable kingdom, more variegated than the mind could have imagined—the bark, the wood, the leaves, and lastly the flowers, fragrant with a thousand odours, and emulating the brightest colours of the rainbow. Or, again, if we compare the character of the vegetable, fixed to its native soil, without any inherent power of moving itself, either totally or partially; insensible to the influence of those agents which beget a succession of new feelings and emotions in animals; how contracted in its sphere of relations must we consider the former body, when compared with the latter; and how

incalculably a greater power of creation do the phenomena of animal organization indicate! Gorgeous as are the lilies of the field, so that even Solomon in all his glory was not arrayed like one of these, yet what are they in the effect they produce on the human mind, compared with the lightning of the eagle's eye, or the fire-breathing nostril of the horse? Most assuredly, in our estimation of excellence, the intellectual and moral image will always bear the pre-eminence; and, whether or not the physical conformation may eventually be found to correspond, philosophers have actually classed animals in such an order, that those which manifest the higher degree of intelligence, and of moral feeling, are comparatively higher in the scale.

As instances of the equivocal character of those particular forms of organized matter to which Aristotle alludes, when speaking of the obscure boundary that separates animals from vegetables, *corallines* and substances of that kind may be adduced among animals; and, among vegetables, those green, and in appearance gelatinous *confervæ* which are found in abundance in stagnant ditches during the summer. And these, and similar examples, seem to show that, after a lapse of more than twenty centuries, the difficulty of defining the boundary between animal and vegetable organization still exists; a difficulty which is fully admitted by the principal physiologists of the present day.*

In examining, however, more particularly the preceding opinions of Aristotle, there is one which does not accurately agree with the present state of our knowledge: there is not, namely, that continuity of gradation which he expresses by the term συνέχεια.† There is probably no living philosopher who advocates the opinion that gradual advances may be traced from the state of inanimate matter to that of life: for even Lamarck, who entertains the opinion of a gradation in structure among animals to a very extraordinary extent, considers that the difference between organized and unorganized matter, in other words between living and lifeless matter, is extreme; so that they cannot possibly be ranged in the same line. And he also believes that, however remarkable may be the apparent affinity between plants and animals, they may always be distinguished.‡

But a regular gradation of form cannot even be traced in one and the same kingdom of nature: for, with reference to animals, Cuvier disclaims any attempt to class them so as to form a single series descending gradually from the higher to the lower classes. Such an

* See Macleay's Horæ Entomologicæ, p. 191.

† A modern parallel to this opinion may be found in the geological hypothesis that the simplest forms of animal life occur only in the older strata; more and more complicated forms appearing in the more recent formations. The progress of geology has shown that this is not really the case. See Prof. Sedgwick's Address to the Geol. Soc. p. 2.

‡ Lamarck, Philosoph. Zoolog. tom. i. p. 377, 384; and 398, in note 1.

attempt he thinks absurd; and is far from supposing that, even in a separate class, the last in order are the lowest in the degree of their organization; and still further is he from supposing that the last of a higher class are more highly advanced than the first of the class immediately succeeding. He merely allows that a regularly graduated scale is occasionally observable to a certain extent; and maintains that the universal application of such a principle is inadmissible on any philosophical grounds.* And Lamarck himself agrees with Cuvier in this opinion.

The only formal terms of classification employed by Aristotle are εἶδος and γένος, of the first of which he gives a remarkably precise definition. That definition is really, though not in literal order, as follows:—"an animal *species* is an assemblage of individual animals, in which not only the whole form of any one resembles the whole form of any other, but each part in any one resembles the corresponding part in any other. Thus every horse not only resembles every other horse generally, but the eye or the hoof of every horse resembles the eye or hoof of every other horse. And the same statement is applicable to man and other animals. They are therefore the same in the character of their individual parts."

("Εχει δὲ τῶν ζώων ἔνια μὲν πάντα τὰ μόρια ταὐτὰ ἀλλήλοις, ἔνια δ' ἑτερα. Ταὐτὰ δὲ τὰ μὲν εἴδει τῶν μορίον ἐστιν, οἷον ἀνθρώπου ῥὶς καὶ οφθαλμὸς ἀνθρώπου ῥινὶ καὶ οφθαλμῷ, καὶ σαρκὶ σαρξ καὶ ὀστῷ ὀστοῦν· τὸν αὐτὸν δὲ τρόπον καὶ ἵππου καὶ τῶν ἄλλων ζῴων, ὅσα τῷ εἴδει ταὐτὰ λέγομεν ἑαυτοῖς· ὁμοίως γὰρ ὥσπερ τὸ ὅλον ἔχει πρὸς τὸ ὅλον, καὶ τῶν μορίων ἔχει ἕκαστον πρὸς ἑκαστον. p. 1.)

In comparing the preceding definition of Aristotle with the corresponding difinition of Cuvier, we find that there is no essential difference. Cuvier says, "Every organized body has, exclusively of the common qualities of its tissue, a peculair or proper form; not only generally and externally, but even in the detail of the structure of each of its parts.† And all the individuals belonging to one of these defined forms constitute what is called a *species*."‡

Aristotle thus defines the term γένος. "A *genus* is an assemblage of individuals, in which any one bears, upon the whole, an obviously perceptible resemblance to any other. Thus birds and fish constitute two distinct genera; each comprehending several species. But the corresponding parts, in the different *species* of the same genus, usually differ in colour, form, number, size, or proportion. In different *genera*, indeed, the difference of corresponding parts occasionally proceeds still further; the only resemblance being that of analogy, as between a scale and a feather; a scale being to a fish, what a feather is to a bird."

* Règne Animal, pref. p. xx, xxi.

† Chaque corps organisé, ontre les qualités communes de son tissu, a une forme propre, non-seulement en général et à l'exterieur, mais jusque dans le détail de la structure de chacune de ses parties. Tom. i. p. 16.

‡ Et tous les êtres appartenans à l'une de ces formes constituent ce que l'on appelle une *espèce*. Tom. i. p. 19.

Τὰ δὲ ταὐτὰ μέν ἐστιν, διαφέρει δὲ καθ' ὑπεροχὴν καὶ ἔλλειψιν, ὅσων τὸ γένος ἐστὶ ταὐτόν. λέγω δὲ γένος οἷον ὄρνιθα καὶ ἰχθύν· τούτων γὰρ ἑκάτερον ἔχει διαφορὰν κατὰ τὸ γένος, καὶ ἔστιν εἴδη πλείω ἰχθύων καὶ ὀρνίθων. Διαφέρει δὲ σχεδὸν τὰ πλεῖστα τῶν μορίων ἐν αὐτοῖς παρὰ τὰς τῶν παθημάτων ἐναντιώσεις, οἷον χρώματος καὶ σχήματος, τῷ τὰ μὲν μᾶλλον αὐτὰ πεπονθέναι τὰ δε ἧττον, ἔτι δὲ πλήθει καὶ ὀλιγότητι καὶ μεγέθει καὶ σμικρότητι καὶ ὅλως ὑπεροχῇ καὶ ἐλλείψει. p. 1. 'Αλλ' ὡς εἰπεῖν τὰ πλεῖστα καὶ ἐξ ὧν μερῶν ὁ πᾶς ὄγκος συνέστηκεν, ἢ ταὐτά ἐστιν ἢ διαφέρει τοῖς ἐναντίοις καὶ καθ' ὑπεροχὴν καὶ ἔλλειψιν.—Ἔνια δὲ τῶν ζῴων οὔτε εἴδει τὰ μόρια ταὐτὰ ἔχει οὔτε καθ' ὑπεροχὴν καὶ ἔλλειψιν, ἀλλὰ κατ' ἀναλογίαν, οἷον πέπονθεν—πρὸς πτερὸν λεπίς· ὃ γὰρ ἐν ὄρνιθι πτερὸν, τοῦτο ἐν ἰχθύϊ ἐστὶ λεπίς. p. 2.

But although Aristotle used the term γένος, in its primary sense, as applicable to an assemblage of different species having a general resemblance to each other; he extends it indefinitely, so that it is practicably applicable to the modern and more comprehensive terms of *tribe, family, order*, or even *class:* for as we have just now seen, he distinctly applies it to the class of fish, and of birds. And it is remarkable that he sometimes uses the term γένος as synonymous with εἶδος, or even a still lower denomination; implying, that is, merely an accidental variation in a species.

The following are instances of an undefined use of the term γένος. Having spoken of red-blooded and vertebrated animals, he adds, τα δε λοιπα γένη των ζῴων ἔστι μεν τέτταρα διηρημένα εἰς γένη: (p. 104.) in which passage γένος is first equivalent either to the *species* or to the *genus;* and afterwards to the *order*, or to the *class*, of modern zoologists. In another passage he says, εἰσὶ δε γένη των μελλιττων πλέιω; (p. 287.) where γένος is evidently used as εἶδος.

Aristotle was quite aware of the necessary connexion between the blood, or a fluid analogous to it, and the life of an animal. "Every animal," he says, "possesses a vital fluid, the loss of which occasions its death:" (ἔχει δε και ὑγρότητα πᾶν ζῷον, ἧς στερισκόμενον—φθείρεται. p. 7.) and as the colour of this fluid in the higher classes of animals is always red, (ἔστι δε τὴν φύσιν τὸ αἷμα—ἔχον—τὸ χρωμα ἐρυθρόν. p. 75.) hence, for the purpose of distinctive description, he assumes the colour as an essential quality; and calls those animals which have red blood ἔναιμα, and those which have not red blood ἄναιμα. And thus he established a fundamental natural division, answering to the red-blooded and white-blooded animals of modern zoology: and it is of great importance, with reference to his principle of classification, to bear in mind that he places the ἔναιμα, or red-blooded animals, in the upper part of his scale.

Aristotle was also aware that there is a natural connexion between the existence of red blood, and of a spine or back-bone, made up of several distinct portions called vertebræ; (πάντα δε τα ζῷα, ὅσα ἔναιμά ἐστιν, ἔχει ῥάχιν, p. 66, σύγκειται δ' ἡ ῥάχις ἐκ σφονδύλων. p. 65.) and he saw, consequently, the coincidence of these two conditions in the classification of animals: and hence we find vertebrated animals occupying the first division in his scale, as well as in the scale of modern

naturalists; though, in consequence of his desultory method of treating the subject, it requires some care to ascertain the order of his arrangement.

Aristotle begins his work with some observations on the characters of the different component parts of the bodies of animals (and these are subsequently repeated in a more detailed form,) which forcibly remind us of the *tissues* of modern anatomy:* "of the component parts of animals," he says, "some are of the same texture throughout: of which the most general are the blood, and the blood-vessels—the flesh—bone—skin—membranes—hair—fat, &c.

(Τῶν ἐν τοῖς ζώοις μορίων τὰ μέν ἐστιν ἀσύνθετα, ὅσα διαιρεῖται εἰς ὁμοιομερῆ, p. 1. Τῶν δ' ὁμοιομερῶν κοινότατον μέν ἐστι τὸ αἷμα—καὶ τὸ μοριον ἐν ᾧ πέφυκεν ἐγγίνεσθαι (τοῦτο δε καλεῖται φλὲψ,)—καὶ ἡ σὰρξ—ὀστοῦν—δέρμα, ὑμὴν—τρίχες—πιμελή. p. 55.

He then distributes the several classes of animals into those which have blood, and those which have not blood: and though in the first instance his distribution is very confused, yet, when adjusted by subsequent statements, the order of arrangement is as follows. Among those which have blood, are *man*, *viviparous* and *oviparous quadrupeds*, *birds*, *fish*, *cetaceous animals*, and *serpents*.

(Τὰ μεν ἔναιμα—ἄνθρωπός τε καὶ τὰ ζῳοτόκα τῶν τετραπόδων, ἔτι δε καὶ τὰ ᾠοτόκα τῶν τετραπόδων καὶ ὄρνις καὶ ἰχθὺς καὶ κῆτος, καὶ—ὄφις. p. 42.)

Among those which have not blood, are animals naturally divisible into segments, as *insects*; animals of a soft substance throughout, as *cuttle-fish*, &c.; animals having comparatively a soft shell, as *lobsters*, &c.; and those which have a hard shell, as *oysters*, &c.)

("Αλλο δε γένος ἐστὶ τὸ των ὀστρακοδέρμων, ὃ καλεῖται ὄστρεον· ἄλλο τὸ των μαλακοστράκων—οἷον κάραβοι καὶ γένη τινὰ καρκίνων καὶ ἀστακων· ἄλλο τὸ των μαλακίων, οἷον—σηπίαι· ἕτερον το των ἐντόμων. Ταῦτα δε πάντα μέν ἐστιν ἄναιμα. p. 10.

He proceeds then to say, that "after having considered the common attributes and actual differences of animals, we must endeavour to find out the causes of these; for only by a demonstration and comparison of the peculiarities of individuals can we hope to arrive at a natural method of classification."

(Πρωτον τὰς ὑπαρχούσας διαφορὰς καὶ τὰ συμβεβηκότα πᾶσι λάβωμεν. Μετὰ δε τοῦτο τας αἰτίας τούτων πειρατέον εὑρεῖν. οὕτω γαρ κατα φύσιν ἐστὶ ποιεῖσθαι τὴν μέθοδον, ὑπαρχούσης τῆς ἱστορίας τῆς περὶ ἕκαστον. p. 11.)

"And, first, we must compare together the several component members of animals; for the chief differences among animals will

* Anticipations of modern physiological opinions are occasionally observable in Galen also. Thus the following passage clearly contains the germ of Bichât's doctrine of organic sensibility. "In vegetables there is a peculiar power of sensation, by which, though incapable of sight, or hearing, &c. they are capable of distinguishing between those particles of matter which will nourish them, and those that will not; attracting the one, and rejecting the other."

("Ετερον εστι γένος αισθησεως ἐν τοις φυτοῖς—οὔτε γαρ των ὁρατων, οὔτε των ακουστικων κ. τ. λ. εχει διαγνωσιν, αλλα μονον των τρεφειν η μη τρεφειν δυναμεων· τα μεν γαρ τρεφειν δυναμενα προς εαυτην ελκουσα κ. τ. λ. μεταβαλλει προς το οικειον της τρεφομενης ουσιας, τα δε μη δυναμενα τρεφειν ου προσιεται.—GALENI OP. Kuhn, vol. iv. p. 764.)

be found in the presence or absence of particular members, and in their order or position; or in their form, proportion, the analogy of their uses, or the peculiarities of their colour, &c."

(Ληπτέον δε πρωτον τα μέρη των ζώων ἐξ ὧν συνέστηκεν. Κατὰ γὰρ ταῦτα μάλιστα καὶ πρῶτα διαφέρει καὶ τὰ ὅλα, ἢ τῷ τὰ μὲν ἔχειν τὰ δὲ μὴ ἔχειν, ἢ τῇ θέσει καὶ τῇ τάξει, ἢ καὶ κατὰ τὰς εἰρημένας πρότερον διαφορὰς, εἴδει καὶ ὑπεροχῇ καὶ ἀναλογίᾳ καὶ τῶν παθημάτων ἐναντιότητι. p. 11.)

In the same philosophical spirit, and in terms not essentially different, Cuvier affirms that, in the attempt to establish a natural classification, he examined one by one all the species that he could procure; and then classed together as a subordinate generic group all those which, resembling each other in the more important parts of their structure, differed only in size, or in colour, or in other points of little importance." (J'ai examiné une à une toutes les espèces que j'ai pu me procurer en nature; j'ai rapproché celles qui ne différaient l'une de l'autre que par la taille, la couleur, ou le nombre de quelques parties peu importantes, et j'en ai fait ce que j'ai nommé un sous-genre. Pref. p. xii.)

In the examination of the component members of animals in general, Aristotle selects man as a standard of comparison; alleging as a reason, that, as merchants estimate the value of foreign coin by a comparison with that of their own country, because best known to them; so in making a classification of animals we naturally employ man as a standard, because we are more familiar with the human form than with that of any other animal.

(Πρῶτον δὲ τὰ τοῦ ἀνθρώπον μέρη ληπτέον· ὥσπερ γὰρ τὰ νομίσματα πρὸς τὸ αὑτοῖς ἕκαστοι γνωριμώτατον δοκιμάζουσιν, οὕτω δὴ καὶ ἐν τοῖς ἄλλοις· ὁ δ' ἄνθρωπος τῶν ζώων γνωριμώτατον ἡμῖν ἐξ ἀνάγκης ἐστίν. p. 11.)

And, man being admitted as the standard of comparison, it necessarily follows that, as a general rule, viviparous animals, birds, reptiles, and fish, would respectively come next in succession: and that order, as we have just seen, Aristotle actually observes. In one instance, indeed, he for a specific reason inverts the order of arrangement; and, commencing with those animals which least resemble man in their organization; and proceeding with those which bear a nearer and nearer resemblance to him; he terminates his description with man, as having the most complicated structure of all animals.

('Επεὶ δὲ διήρηται τὰ γένη πρῶτον, τὸν αὐτὸν τρόπον καὶ νῦν πειρατέον ποιεῖσθαι τὴν θεωρίαν· πλὴν τότε μὲν τὴν ἀρχὴν ἐποιούμεθα σκοποῦντες περὶ τῶν μερῶν ἀπ' ἀνθρώπον, νῦν δε περὶ τούτου τελευταῖον λεκτεόν διὰ τὸ πλείστην ἔχειν πραγματείαν. p. 112.)

And he then enumerates the several classes in the following order; "animals having a hard shell; animals having a soft shell; mollusca, or animals of a soft substance throughout; insects; fish; birds; oviparous and viviparous quadrupeds; and man: by inverting which order we arrive at a correct view of his original arrangement."

(Πρῶτον δ' ἀρκτέον ἀπὸ τῶν ὀστρακοδέρμων, μετὰ δὲ ταῦτα περὶ τῶν μαλακοστράκων, καὶ τὰ ἄλλα δὲ τοῦτον τὸν τρόπον ἐφεξῆς· ἔστι δὲ τά τε μαλάκια καὶ τὰ ἔντομα, καὶ μετὰ ταῦτα τὸ τῶν ἰχθύων γένος, τό τε ζωοτόκον καὶ τὸ ᾠοτόκον αὐτῶν, εἶτα τὸ τῶν ορνιθων. μετὰ δὲ ταῦτα περὶ τῶν πεζῶν λεκτέον, ὅσα τε ζωοτόκα καὶ ὅσα ᾠοτόκα δ' ἐστὶ τῶν τετραποδων ἔνια, καὶ ἄνθρωπος τῶν διπόδων μόνον. p. 112.)

It is remarkable that, from the age of Aristotle to nearly that of Linnæus, no systematic classification of animals was attempted; none, at least, was generally adopted. Soon after the commencement of the last century Linnæus directed his attention to the subject; and distributed the whole animal kingdom into six classes, mammalia, birds, reptiles, fish, insects, and worms: in which distribution Lamarck observes that he improved on Aristotle, first, by using the more distinctive term *mammalia*, and placing the *cetacea* in that class; and, next, by making a distinct class of *reptiles*, and arranging them between birds and fish. If this alteration, which has been subsequently adopted by all other zoologists, be made, Aristotle's arrangement of vertebrated animals agrees with that of the present day. And in distributing all other animals into *four* classes, which Linnæus distributes into *two* only, Aristotle must be considered as having proceeded upon the more philosophical principle; because the species of these animals, taken collectively, are much more numerous, and much more diversified in their form and structure, than the species of vertebrated animals. Lamarck's objection to Aristotle's arrangement, on the ground of its commencing with animals of a more complicated instead of those of a more simple structure, is, for more than one reason, of little weight: for, in asserting that such an arrangement is contrary to the order of nature, he makes a peculiar hypothesis of his own the basis of that assertion; and, with the exception of Lamarck himself, almost if not all modern naturalists, including Cuvier, adopt the same principle of arrangement as that of Aristotle.

Lamarck objects with more justice to the terms ἔναιμα and ἄναιμα, as also to the supposed improvement of some modern naturalists by the substitution of the equivalent terms, *red-blooded* and *white-blooded;* because in the second of those two divisions some species are included, as worms, &c. which have red blood. On this ground Lamarck proposed to divide all animals into those which have, and those which have not, vertebræ; or into *vertebral* and *invertebral* animals.* And he extended the *two* invertebral classes of Linnæus to *five*, and subsequently to *ten*.†

With reference to the classification of Aristotle, as expressed in his first book, it has been occasionally observed by literary men, who were not familiar with the details of his history, that quadrupeds in general and reptiles are excluded. "The most comprehensive groups into which the greater number of animals may be

* Philos. Zool. tom. i. p. 116, &c.

† Ibid. p. 121, 122.

distributed," he says, "are these: one, of birds; one, of fish; one, of whales and other cetaceous animals; all of which have blood. There is another group of the ὀστρακοδέρμα; another, of the μαλακόστρακα; another, of the μαλακια; and another, of the ἔντομα; all of which are without blood. Of those animals which do not come within the foregoing arrangement, there are no comprehensive groups; for no individual type comprehends many species: and there is one type which is unique, affording only a single species, namely, man. Some types afford different species without a difference of specific denomination: thus there are red-blooded quadrupeds, of which some are "viviparous, and others oviparous."

(Γένη δὲ μέγιστα τῶν ζώων, εἰς ἃ διήρηται τἆλλα ζῷα, τάδ' ἐστὶν, ἓν μὲν ὀρνίθων, ἓν δ' ἰχθύων, ἄλλο δὲ κήτους. Ταῦτα μὲν οὖν πάντα ἔναιμά ἐστιν. ἄλλο δε γένος ἐστὶ τὸ τῶν ὀστρακοδέρμων—ἄλλο τὸ τῶν μαλακοστράκων—ἄλλο τὸ τῶν μαλακίων—ἕτερον τὸ τῶν ἐντόμων. Ταῦτα δε πάντα μέν ἐστιν ἄναιμα—Τῶν δε λοιπῶν ζώων οὐκέτι τὰ γένη μεγάλα· οὐ γὰρ περιέχει πολλὰ εἴδη ἓν εἶδος, ἀλλὰ τὸ μέν ἐστιν ἁπλοῦν αὐτὸ οὐκ ἔχον διαφορὰν τὸ εἶδος, οἷον ἄνθρωπος, τὰ δ' ἔχει μεν, ἀλλ' ἀνώνυμα τὰ εἴδη. Ἔστι γὰρ τὰ τετράποδα καὶ μὴ πτερωτὰ ἔναιμα μεν πάντα, ἀλλὰ τὰ μεν ζῳοτόκα τὰ δ' ᾠοτόκα αὐτῶν. p. 10.)

And though there are many species of viviparous quadrupeds, yet they have no collective denomination; but each is distinguished, as in the case of the human species, by its proper name; as the lion, deer, horse, &c. on which account we cannot describe them collectively, but must consider the individual nature and character of each."

(Τοῦ δε γένους τοῦ τῶν τετραπόδων ζώων καὶ ζῳοτόκων εἴδη μέν ἐστι πολλὰ, ἀνώνυμα δέ· ἀλλὰ καθ' εκαστον αὐτῶν ὡς εἰπεῖν, ὥσπερ ἄνθρωπος εἴρηται, λέων, ἔλαφος, ἵππος—Διὸ καὶ χωρὶς λαμβάνοντας ἀνάγκη θεωρεῖν εκάστου τὴν φύσιν αὐτῶν. p. 10.)

It is interesting to observe that even Cuvier occasionally experiences a similar difficulty in his classification; and expresses himself, with reference to the difficulty, in nearly the same terms as Aristotle. Thus, in introducing his third order of the mammalia, called *carnivora*, he says, "The forms of the different genera of this order are so various, that it is impossible to range them in the same series: they are therefore divided into several families.* And of one of these families, the *marsupialia*, to which the oppossum and kanguroo belong, he observes, that "the genera of that family might form a distinct *order*, so very peculiar is their structure.† And on another occasion he adds, with respect to this same family, that "although the various species so closely resemble each other in many points as for a long time to have been classed in one genus

* Les Carnassiers.—Leurs formes et les détails de leur organisation varient beaucoup—au point qu'il est impossible de ranger leurs genres sur une meme ligne, et que l'on est obligé d'en former plusieurs familles qui se lient diversement entre elles par des rapports multipliés. tom. i. p. 121.

† Les Marsupiaux—pourraient presque former un ordre à part, tant ils offrent de singularités dans leur économie." tom. i. p. 169.

only; they yet differ so widely in their feet, and teeth, and organs of digestion, that, considered with reference to those parts, they might be distributed, not into one but several *orders*;*—and might constitute even a separate and parallel *class* of mammalia.†

In addition to the natural groups, enumerated in the distribution above described, Aristotle refers to a few marine animals which principally belong to the zoophytes of Cuvier, without comprehending them under a distinct name. Of that extensive class of animals, called at the present day *polypes*, which are the fabricators and inhabitants of every variety of coral, he says nothing: and of that still more extensive class, if the term *class* be not too confined, the *animalia infusoria*, he was almost necessarily ignorant; most of the species being microscopic.

It appears, from a few scattered notices, that Aristotle had a faint idea that the specific characters and dispositions of animals might be altered, from the effect of food and other circumstances: (τῶν ζῴων τῶν τετραπόδων πολλὴν αἱ χωραι ποιοῦσι διαφορὰν οὐ μόνον πρὸς τὴν ἄλλην τοῦ σώματος εὐημερίαν ἀλλα καὶ πρὸς τὸ πλεονάκις ὀχεύεσθαι καὶ γεννᾶν. p. 122. Ὅσα μεν οὖν μαλακὰς ἔχει τας τρίχας, εὐβοσίᾳ χρώμενα σκληροτέρας ἴσχει, ὅσα δε σκληρας, μαλακωτέρας καὶ ἐλάττους. Διαφέρουσι δε καὶ κατα τοὺς τόπους τοὺς θερμοτέρους καὶ ψυχροτέρους. p. 68.) Ἐνίοτε γίνεται των μονοχρόων ἐκ μελάνων τε καὶ μελαντέρων λευκα—ἐκ δε των λευκων γενων οὐκ ὦπται εἰς μελαν μεταβάλλον. p. 71.)

And he mentions particularly one instance of this kind, though his reasoning on the occasion is not admissible in the present state of physiological knowledge. In observing that, "as the actions of animals are determined by their natural affections and physical powers, so their moral habits, and even some of their physical characters, are capable of being altered by their actions;" he says, that "the common hen, if she have fought with and vanquished the cock, will begin to crow, and to imitate the cock in various ways; and her comb will increase, and her plumage alter to such a degree as to make it difficult to determine whether she be really a hen: even spurs, though small, will sometimes grow on her legs.

(Ὥσπερ δε τας πράξεις κατα τα πάθη συμβαίνει ποιεῖσθαι πᾶσι τοῖς ζῴοις, οὕτω πάλιν καὶ τα ἤθη μεταβάλλουσι κατα τας πράξεις, πολλάκις δε καὶ των μορίων ἔνια, οἷον ἐπὶ των ὀρνίθων συμβαίνει. Αἵ τε γαρ ἀλεκτορίδες ὅταν νικήσωσι τοὺς ἄρρενας, κοκκύζουσί τε μιμούμεναι τοὺς ἄρρενας καὶ ὀχεύειν ἐπιχειροῦσι, καί τό τε κάλλαιον ἐξαίρεται αὐταῖς καὶ τὸ οὐροπύγιον, ὥστε μὴ ῥᾳδίως ἂν ἐπιγνωναι ὅτι θήλειαί εἰσιν· ἐνίαις δε καὶ πλῆκτρά τινα μικρα ἐπανέστη. p. 302.)

The fact is nearly as Aristotle states it; and, to a certain ex-

* Malgré une ressemblance générale de leurs espèces entre elles, tellement frappante, que l'on n'en a fait long-temps qu'un seul genre, elles diffèrent si fort par les dents, par les organes de la digestion et par les pieds, que si l'on s'en tenait rigoureusement à ces caractères, il faudrait les répartir entre divers ordres. p. 170.

† On dirait, en un mot, que les marsupiaux forment une classe distincte, parallèle à celle des quadrupèdes ordinaires. p. 171.

tent, similar facts are observable in the human species as well as in other animals; namely, that the peculiar characters of the female are occasionally obscured, with respect both to the physical form and the moral habits. But, in reasoning on the phenomena, Aristotle mistakes the effect for the cause. The circumstance of having fought with the cock is not the determining cause of the change in the external form of the hen: but the alteration itself in the external form is dependent on, or at least coincident with an imperfect developement, or a subsequent alteration, of the internal structure; which imperfect developement or subsequent alteration determines that degree of masculine courage which prompts the hen to fight, and to imitate the male in other actions.

And so it sometimes happens that, in females of the human species, the feminine form is either never originally developed, or, by age or other causes, becomes so much altered as to lose its usual characters; (*γυνὴ δε τας ἐπὶ τῷ γενείῳ οὐ φύει τρίχας· πλὴν ἐνίαις γίγνονται ολίγαι, οταν τα καταμήνια στῆ.* p. 70.) and, correspondently with these exterior traces of virility, there is often in such cases a masculine temperament of the mind, which marks the character of the virago. And, on the other hand, from analogous causes analogous changes are found to take place in the male of our own species, or of any species nearly resembling our own: for, in such instances, the tone of the voice and the general form of the body acquire a feminine character; and that firmness and resolution, which belong naturally to the male, subside to a greater or less degree into a feminine gentleness.

Aristotle, then, had no philosophical notion of the laws which regulate the occasional variation in the specific form of animals; much less of the limits of that variation: for the accurate developement of which, the scientific world, and more than the scientific world, are deeply indebted to the skilful researches and correct reasonings of Cuvier; whose fame will rest securely on this natural and imperishable basis, when his own and all other artificial systems of classification, for artificial we can see them to be even in the present state of our knowledge, will probably have been overturned by the force of those new views of nature, which must necessarily result from the contemplation of the numerous and varied phenomena which are rapidly accumulating in this department of knowledge. The field, indeed, in which Cuvier has laboured, with such advantage to science as well as honour to himself, is the investigation of the conditions which accompany the developement of individual and specific form: and the result of his labours has afforded a splendid instance of the wonderful effect which the powers of the human mind are capable of producing, in a subject apparently of the least intrinsic interest and of the most unpromising aspect. The explanation of his views which I shall now attempt to offer, while it may tend to make known the particular merits of

this philosopher to a class of readers, who at present are acquainted with little more of him than his great name, will certainly accord with the general object of this treatise.

In the preliminary discourse of his work entitled "Ossemens Fossiles," he states that the great principle in the study of comparative anatomy is this—that in every animal the several parts have such a mutual relation, both in form and function, that if any part were to undergo an alteration, in even a slight degree, it would be rendered incompatible with the rest; so that if any part were to be changed, all the other parts must undergo a corresponding change: and thus any part, taken separately, is an index of the character of all the rest. This law of the co-relation of parts is indeed so defined, that even a portion of a bone may often serve to verify the species of the animal to which it belonged. (p. xlv.)

We know how successfully Cuvier has applied the foregoing principle in establishing the true character of fossil species, of which the imperfect remains, or fragments of remains, are both few and of rare occurrence. The permanency however of specific character does not hold in every part of the organisation; and hence there is an occasional impediment to the application of the principle: but the variation never proceeds beyond certain limits; and therefore no more interferes, eventually, with the uniformity of the specific character of animals, than the periodical oscillations of the celestial bodies counteract the general regularity of their motions.

We are now therefore to consider the nature of the disturbing cause, if I may borrow that expression for a moment, which occasionally interferes with the uniformity of specific character. And, with respect to specific forms, it may be remarked, that, although it is to a certain extent true that all organised bodies have the power of producing beings resembling themselves, yet circumstances of temperature, and of quantity or quality of food, and other causes, have usually some influence in the developement of the body of each individual; thereby producing some corresponding variation in the form: and, consequently, the resemblance between the parent and offspring is never perfect. But—and this is a fact of the highest importance—there is no ground for believing that such variations proceed beyond certain limits; no ground therefore for believing that any of the above-mentioned circumstances could have produced all the differences perceptible in organised bodies; could have advanced for instance, by a gradual alteration of structure, a lower to a higher species. Experience, on the contrary, founded on an examination of the records of remote antiquity, seems to show that the limits of variation were ever the same that they are now. It appears for instance from the mummies of Egypt,* that the general form, and size, and proportions were the same three thousand years since, that they are at present; as well in various other animals as in

* Vid. Cuvier, Oss. Foss. i. Disc. Prelim. p. 75, 80.

man; and in all physiological probability therefore were the same three thousand years before that period: so that we cannot refuse to admit, that certain forms have, without exceeding the limits above described, been perpetuated from the creation.

From various circumstances, however, as has been already stated, the offspring never exactly resembles the parent; and by the extension of those causes which occasion a difference of character, the variation from the common parent may possibly become so great, and so permanent in individuals of the same species, as to exceed in some respects the difference observable in individuals of different species. Such appears to be the fact, when, in the dog species, we compare the grayhound with the turnspit; or the Newfoundland dog with the Blenheim spaniel: and yet, even in such instances, which perhaps may be considered as comprising the extreme limits of variation, the specific character is never so far obscured, but that a child who had been accustomed to see a variety of dogs, and also of other animals, would recognise the character of the dog in each individual of that species.

It is true, indeed, that it would be difficult not only for a child, but even for the most experienced observer, to define those characters by which the specific resemblance is recognised upon a transient view of the animal. Yet, although not obvious on a superficial examination, nature has not left this point undefinable: for, in almost every instance, the form and number of the bones are so accurately preserved, that, however the colour, or the size and the general form of the body may be altered, we have satisfactory criteria of the species in the points just mentioned. But, of all the constituent parts of the body, this observation holds most eminently with respect to the teeth: and in the case of quadrupeds, which principally constitute the highest class of the animal kingdom, and in which class alone any considerable degree of variation is likely to be observed, we have almost always a ready mode of judging of the identity of specific character by an examination of the teeth; for they in almost every instance have teeth, which are entirely wanting throughout the whole class of birds, and often in reptiles and in fish.

In investigating the remote causes of specific variation, we find that domestication is the most general and extensive; and that the effects are produced principally by the joint operation of the following means, namely, diet, general regimen, and the due selection of individuals for the purpose of breeding.*

* Burckhardt observes, in his notes on the Bedouins, p. 111, and 139, that in barren parts of the desert of Arabia, or in seasons of scarcity, camels and sheep do not multiply so extensively as in fertile plains and seasons. A similar observation would probably hold good with respect to the ratio of increase among the Tchutzki and other tribes of north-eastern Russia, and the inhabitants of New Holland or any other part of the world where the supply of food is scanty.

See, on this subject, a letter, published by Sir John Sebright in 1809, on the art of improving the breeds of domestic animals.

While animals exist in a state of nature, it does not appear that the circumstances in which they are placed give rise to much variation, even in their external and fugitive characters. A uniformity of size and colour is usually observable in the several individuals of the same species; as in the instances of the wild cat and rabbit. Nor is the character liable to be changed by intercourse among individuals of different species. Although, for instance, the hare and rabbit are so nearly allied in form and size and colour, we never meet with a hybrid or mule of those species.

In domesticated species a variation first in colour, and then in size, usually takes place, to an extent proportional to the degree of domestication. Cats, which are less subjugated to man than horses or dogs, vary little more than in colour; scarcely at all in size. And in horses, on the same principle, there is a less degree of variation than in dogs. In the dog, which is of all species the most domesticated, the variation extends to the production of an additional toe, and corresponding metatarsal bone in the hind foot.* And in the human species, in the individuals of which, from their varied intercourse and modes of living, the limits of variation may antecedently be expected to have the widest range, there are families having six fingers.

In concluding this part of the subject, I would observe that the principle, which we have just now been examining, is of very great importance as to the basis of a physiological argument with reference to the identity of the human species throughout the world. For, inasmuch as all the variations in colour, form, and size, of the different nations of mankind, come within the acknowledged limits of specific variation in the animal kingdom, we have hence satisfactory physiological proof that all the varieties of the human race may have proceeded from one common parent. Of the truth of the general position indeed, of which the human species is a particular instance, the work of Aristotle now under consideration is in itself a strong argument: for, notwithstanding the lapse of ages which has taken place since it was written, the description of many species is so accurate, as to leave no doubt of the identity of those described by Aristotle with those to which the description is applicable at the present day.†

* Ann. du Mus. tom. xviii. p. 342. pl. 19.

† It can hardly escape observation, or fail to excite surprise, that in the work now under consideration, Aristotle usually contents himself with stating facts: he very rarely reasons on their final causes; thus omitting what Cuvier calls one of the most beautiful and useful points in natural history. The following are, I believe, the only instances in which he deviates from mere description. He observes, when speaking of fish, that a great proportion of the spawn of those animals is destroyed in various ways; and that if this were not the case the species would become too numerous.

(Τὰ μεν πολλὰ ὠὰ οἱ ἄρρενες ανακαπτουσι, τα δ᾽ ἀπολλυται εν τῷ ὑγρῷ· οσα δ᾽ ἂν εκτεκωσιν εις τους τοπους εις ους ἐκτικτουσι, ταυτα σωζεται· ει γαρ παντα εσωζετο, παμπληθες αν το γενος ην εκαστων. p. 169.)

On another occasion he observes, that though the spring is the general season for

Section IV.

On those Animal Forms called Monsters, or Lusus Naturæ.

The subject of the present section is naturally connected with that of the latter part of the preceding: and, although the occasion neither requires nor would justify even a brief examination of the laws which regulate the formation of monsters, or *lusus naturæ*, as they are often called, especially as they have been lately illustrated by that ardent French physiologist Geoffroy St. Hilaire; it will not be perhaps considered impertinent to make a few observations on those remarkable productions, considered with respect to one of the probable final causes of their existence.

The term *lusus naturæ* is applied to those natural productions, which vary in any remarkable degree, with respect to form, colour, structure, size, &c. from the general character of the individuals of the same species. The term literally taken, implies a sportive effort of the creative power of nature; and for the purpose of general description there is no objection to this term, being, as it now is, familiarized by long continued use. But as we have no ground for supposing that nature, or, to use the more proper expression, that the providence of the Creator ever acts without some wise and beneficial purpose, we must consider the term in a philosophical point of view, as expressing an effect, of the natural cause of which we are ignorant.

What, then, is the real character of those unusual productions which are denominated *lusus naturæ*, or *monsters;* or, in other words, for what end has Providence ordained that such productions should be formed and subjected to our observation? And here, as has been observed in another part of this treatise, it will be found, upon even a cursory examination, that in a *lusus naturæ* the character of the species, however obscured, is never lost. There is no ground, in short, for supposing that nature has ever produced such an individual as a chimera or centaur. And Lucretius's scepticism in this point is justified on truly philosophical principles; on the difference namely of the physical constitution of the horse and of man: the horse at the end of his third year being full-grown, while man is yet almost an infant; and a horse being decrepit in his twenty-fifth or thirtieth year, when man is in his full vigour.*

propagation, yet occasionally the rule is set aside; where, for instance, the preservation of the offspring is the result.

(*Ορμετικώτατα μεν ουν ως επι το παν ειπειν προς την οχειαν την εαρινην ὥραν εστιν· ου μην τα παντα γη ποιείται τον αυτον καιρον της οχειας, αλλα προς την εκτροφην των τεκνων εν τοις καθηκουσι καιροις.* p. 181.)

* Sed neque Centauri fuerunt, neque tempore in ullo
Esse queat duplici natura, et corpore bino
Ex alienigenis membris compacta potestas—
Principio, circum tribus actis impiger annis
Floret equus, puer haudquaquam, &c.——Lib. V. 876—889.

In pursuing this investigation, it would be obvious to ask, what are the limits which separate a *lusus naturæ* from the ordinary individuals of the same species? and we shall soon find that these limits are, in the majority of instances, undefinable.

If, indeed, in comparing the several organs, agreement with respect to number be the criterion, the limits are for the most part fixed. Thus the human hand so very generally consists of five fingers, that an instance of an individual having more or less than five fingers would be justly esteemed an instance of a *lusus naturæ.* But even number is not always an acknowledged criterion; for, with respect to the teeth, though thirty-two is the usual number in the human subject, yet the instances of persons having only twenty-eight are so frequent, that we can scarcely class them as deviations from the common law.

But if size, or colour, or form be made the criterion, we evidently cannot then fix the limits; for in all these points there is an endless variety in individuals of the same species: so that it might perhaps be truly asserted, that out of the countless myriads of human beings that inhabit the earth, nay even out of all that have existed since the creation, no two individuals would be found to resemble each other exactly, in even any one of those points. And in this wonderful diversity the infinite power of the Deity is distinctly manifested: for, in the exercise of human skill, the most accomplished artist, as soon as he ceases to copy an actual individual, falls into that general similarity of outline by which we are enabled to ascertain his style upon the first view.

If, in the pursuit of our inquiry, we appeal to the distribution of the internal organs of the body, we shall find, that though with respect to many the position is determinable with considerable precision, yet with respect to others, the smaller veins and arteries, for instance, the variation is endless. But—and this most highly deserves our attention—if we consider the *uses* of the parts with reference to the precision of their position, we shall find, that the position of those is most constant, the uses of which are most important; while the distribution of those parts, the position of which may differ to a considerable extent without inconvenience to the individual, is found to be continually varying.

Now as this law of deviation from the usual structure does not seem at all to depend on the construction of the parts themselves; and as the result is necessarily connected with the well-being, and even the life, possibly, of the individual; we cannot consider this result as the effect of chance, or want of design: for, if chance could be admissible as the cause, why should one class of phenomena be so much more frequent than the other? And with equal or still greater force we may apply the argument to the existence of those productions emphatically called *monsters.* Probably then, or rather assuredly, these anomalous productions may, in addition to other ends, be con-

sidered as proofs of a particular or constantly superintending Providence; and, like the storms which occasionally ravage the surface of the earth, may awfully recall to our minds the power of the Deity, while they at the same time convince us, by the rarity of their occurrence, of the merciful beneficence of his nature.

CHAPTER XI.

CONCLUSION.

It has been the immediate object of the preceding treatise to demonstrate the adaptation of the external world to the physical condition of man: and, either in considering him merely as an individual, or as a component member of any stage of society, it may be freely admitted that every step in the investigation has tended to confirm this general conclusion, that—whether from chance, (if any philosophical mind acknowledge the existence of such an agent as chance,) or from deliberate design—a mutual harmony does really exist between the corporeal powers and intellectual faculties of man, and the properties of the various forms of matter which surround him; the material constituents of all nature being as evidently adapted to the supply of the wants of his body, as the contemplation of their causes and relations to the exercise of his mind.

We have seen that from the surrounding atmosphere he is constantly supplied with that respirable part of the air, which alone can support the breath of life; and which is demanded for that purpose during almost every moment of his existence. We have seen that from the same source are derived those universal and important agents, water and heat and light, which are equally though not so immediately necessary, as air, to the wants of man. We have seen again, that the mineral kingdom, though it does not directly contribute to the support of life, yet in the form of natural soils sustains the growth of every kind of vegetable; and that on the nutriment derived from this source all animal life essentially depends: we have seen that the same source also supplies those various metallic and earthy bodies, the uses of which are most extensive and important in promoting many of the arts of civilized society. And, lastly, that the advantages derivable from the vegetable and animal kingdoms are, eventually, neither of less extent and importance, nor their adaptation to the physical condition of man less obvious, than those of the mineral and atmospherical.

It would have been easy to demonstrate that an equally obvious

but infinitely more important harmony exists between the external world, and the moral condition of man, as between that world and his physical condition: but this province had been assigned to others; and all systematic reference to that harmony has therefore been studiously avoided—though the constantly recurring difficulty has been to abstain from such a demonstration.

But, it may possibly be observed, both the physical and moral relations of man are inevitably soon cut short by death: and though, in many instances, societies continue to be benefited through successive ages in consequence of the efforts of individuals, who have long since ceased to live, yet in many instances, on the other hand, the memorial not only of individuals, but of nations also, entirely perishes; and all things apparently proceed, as if those individuals and nations had never existed.

Shall we then, in concluding this treatise, simply admit the existence of that harmony, the illustration of which was its professed object; and in admitting that existence shall we at the same time express our gratitude to that Power, which has thus amply provided for the physical wants of man, and for the developement of his intellectual faculties? That indeed would have been incumbent on us under any circumstances; and without any qualification arising from the partial occurrence either of disease, or famine, or any other form of physical evil.

But, since they, to whom this treatise is addressed, are conscious that some ulterior cause exists for the adaptation of the external world to the nature of man, beyond the transient supply of his physical wants, or even the exercise of his intellectual faculties; to have exhibited the bare fact of that adaptation, without some reference to its final cause, would have been to leave the whole argument without its just conclusion.

Avoiding however the presumption of speculating on the nature of a future state of existence, we may, without any impropriety, assert, on the authority of revelation, that the happiness or misery of that state will depend much on the use we have made of that external world which surrounds us; and will coincide with the prevailing character of those habits which we have contracted in this life.

This then is the sum of the whole argument. The Creator has so adapted the external world to the moral as well as the physical condition of man, and those two conditions act so constantly and reciprocally on each other, that in a comprehensive view of the relation between the external world and man, we cannot easily lose sight of that most important connexion. And, if we extend our views to a future life, we are taught that the moral state, which has been induced by our prevailing animal or intellectual habits in this life, will be continued and perpetuated eternally in the next—"that in the place where the tree falleth, there it shall be"—that "it is appointed unto men once to die; but after this, the judgment."

Have we then, to refer first to our animal wants and desires, have we indulged without restraint in the pleasures of sense; shrinking from every breath of heaven, unless previously tempered with luxurious warmth, and impregnated with the perfumes of the east? Have we weakened our intellectual faculties, and brutalized our moral feelings, by habitual inebriation; abusing that gift of Heaven, which was intended as a restorative of exhausted nature? Instead of simply satisfying the calls of hunger by plain and moderate diet, have we provoked and pampered the appetite by all the luxuries which the animal and vegetable kingdoms can supply, till at length all appetite has been destroyed; pain and disease have been induced; the human form and feature have been lost under a mass of loathsomeness and corruption; and death, long wished for, yet dreaded, has arrived at last? we shall awake hereafter in another world, but in unaltered misery; without the hope of any second offer of release from the impurity and everlasting punishment of sin.

Or, to refer to the intellectual part of our nature, in contemplating for instance the starry firmament, and in calculating the unerring motions of the heavenly bodies, have we been content to characterise the certainty and regularity of those motions as the result of necessity, or of the laws of an undefined agent called *nature?* And in thus failing to acknowledge explicitly the Author of those laws, though not indeed formally denying his existence, have we, like the nations of old, worshipped the creature, rather than the Creator; and bowed down our knee, as it were, to the host of heaven?—we may in that case hereafter suffer the penalty of our intellectual pride, in a mode severely just. The mind, which in this life failed to exercise its highest functions by adoring the Deity in the contemplation of his works, may be forbidden to extend the exercise of those functions in the next; and, while it looks back with unutterable torment to the forfeited pleasures of its former state, may be condemned, with torment infinitely increased, to expatiate eternally through new fields of knowledge, without the capability of even putting the sickle to the boundless harvest which they present.

But if, happily, we have pursued a wiser course; if, with Newton, we have delighted to deduce from the contemplation of the mechanism of the heavenly bodies the power of Him who made them, and who alone sustains and directs their motions; we may, and with faculties infinitely expanded, cultivate with him the same pure pleasures, which even on earth abstracted his desires from earthly wants; and, enraptured with the harmonious movements of those endless systems, which neither our present organs can see, nor our present faculties apprehend, we may continue to be constantly acquiring new knowledge, constantly absorbed in new wonder and adoration of that Power, from whom, both in this world, and in that which is to come, all knowledge, and every other good and perfect gift are alone derived.

APPENDIX.

Having considered in the preceding pages the general opinions of Aristotle respecting the physiology and classification of animals, I propose in this Appendix to make a selection from his descriptions of some natural groups and individual species of animals, for the purpose of comparing them with the corresponding descriptions of Cuvier; confining myself, however, exclusively to the mammalia, which constitute the first class of vertebrated animals. And, as an introduction to that selection, I shall prefix a comparative view of the observations of the same two authors on some points connected with the general physiology of animals; presenting the whole in the form of two parallel columns, as the most convenient mode of exhibiting the comparison. In each column I shall endeavour to give a free but faithful translation of the original passages, followed by the original passages themselves.*

However extensive may have been the information of the ancients in that department of natural science which is now under consideration; and however capable a mind like that of Aristotle must have been of deducing general conclusions from a systematic examination of facts, sufficiently numerous and various, for the purpose of effecting a natural classification of animals, it could not reasonably be expected that, antecedently to the knowledge of the circulation of the blood, and of the true character of respiration, and also of the physiology of the absorbent and nervous systems, a natural classification could have been accomplished on principles so satisfactory as at the present day. And those individuals pay a very absurd homage to antiquity, who, on occasions like the present, would place the pretensions of the ancients upon an equality with those of the moderns: for the question does not regard the original powers of the mind, but the amount of accumulated knowledge on which those powers are to be exercised; and it would indeed be extraordinary if, inverting the analogy of individuals, the world should not be wiser in its old age, than it was in its infancy.

In comparing, then, the zoology of Aristotle with that of the moderns, it has not been my intention to prove that the classification of the one is built upon equally clear and extensive demonstrations as that of the other; but to show, as in harmony with the general object of this treatise, that, even in the very dawn of science, there is frequently sufficient

* In order to abridge as much as possible the number and length of the extracts, I have occasionally merely stated a conclusion drawn from several separate paragraphs. In such instances I must claim credit for having rightly understood, and fairly represented, the context.

light to guide the mind to at least an approximation to the truth—to a much nearer approximation, indeed, than could have been antecedently expected by those who are not accustomed to reflect philosophically on the uniformity of the laws of nature. Thus, as has been already mentioned, the advancement of science has shown the existence of such a general coincidence and harmony of relation between the several component parts of an individual animal, that even a partial acquaintance with the details of its structure will frequently enable the inquirer to ascertain its true place in the scale of organization. And hence, although Aristotle knew nothing of the circulation of the blood, or of the general physiology of the nervous system, and even comparatively little of the osteology of animals, yet subsequent discoveries have scarcely disturbed the order of his arrangement. He placed the *whale*, for instance, in the same natural division with common quadrupeds, because he saw that like them it is viviparous, and suckles its young, and respires by lungs and not by gills; and with viviparous quadrupeds it is still classed; the circulation of its blood, as well as the arrangement of its nervous system, being essentially the same as in that class of animals. And, notwithstanding the difference of its form, its osteology, which holds an *analogy* throughout with that of quadrupeds, is the same *actually* in a part where it would be least expected: for, with the remarkable exception of the sloth, all viviparous quadrupeds have exactly seven cervical vertebræ, and so has the whale; whereas fish, to the general form of which the whale closely approximates, having no neck, have no cervical vertebræ: and the deficiency of the neck in fish was recognised by Aristotle.*

GENERAL PHYSIOLOGY.

Aristotle.

In some animals there is a mutual resemblance in all their parts; as the eye of any one man resembles the eye of every other man: and it is the same with respect to the constituent parts of horses, or of any other animals, which are said to be of the same species: for in individuals of the same species, each part resembles its correspondent part as much as the whole resembles the whole.

Ἔχει δε τον ζῴων ἔνια μεν παντα τα μόρια ταυτα ἀλλήλοις, ἔνια δ' ἕτερα. ταὐ-

Cuvier, tom. I.

Every organized body has its peculiar form: not only generally and exteriorly, but even in the detail of the structure of each of its parts; and all the individuals which agree in the detail of their structure are of the same species.

Chaque corps organisé a une forme propre, non-seulement en gé-

* Αὐχένα δ' οὐδεὶς εχει ἰχθύς. p. 40.

Aristotle.	*Cuvier*, tom. I.
τα δε τα μεν εἴδει των μορίων ἐστὶν, οἷον ἀνθρώπου ῥὶς καὶ ὀφθαλμὸς ἀνθρώπου ῥινὶ καὶ ὀφθαλμῷ, καὶ σαρκὶ σαρξ καὶ ὀστῷ οστοῦν· τὸν αὐτὸν δε τρόπον καὶ ἵππου καὶ των ἄλλων ζώων, ὅσα τῷ εἴδει ταὐτα λέγομεν ἑαυτοῖς· ὁμοίως γαρ ὥσπερ τὸ ὅλον ἔχει πρὸς τὸ ὅλον, καὶ των μορίων ἔχει εκαστον πρὸς εκαστον. p. 1.	néral et à l'extérieur, mais jusque dans le détail de la structure de chacune de ses parties, p. 16, et tous les êtres appartenans à l'une de ces formes constituent ce que l'on appelle une espèce. P. 19.
All animals have certain common organs, by means of some of which they lay hold of, and into others of which they convey their food. The organ by which they lay hold of their food is called the mouth; that, into which they convey it, the stomach: but the other parts are called by various names. The form and relative proportions, structure, and position of these parts, are the same in the same species, but vary in different species of animals.	The leading character of animals is derived from the existence of a reservoir for their food, that is, an intestinal canal, the organization of which varies according to circumstances.
Πάντων δ' ἐστὶ των ζῴων κοινα μόρια, ᾧ δέχεται τὴν τροφὴν καὶ εἰς ὃ δέχεται·—Καλεῖται δ' ᾗ μεν λαμβάνει, στόμα, εἰς ὃ δε δέχεται, κοιλία· τὸ δε λοιπὸν πολυώνυμόν ἐστιν.—Ταῦτα δ' εστι ταῦτα καὶ ἕτερα κατα τοὺς εἰρημένους τρόπους, ἢ κατ' εἶδος ἢ καθ' ὑπεροχὴν ἢ κατ' ἀναλογίαν ἢ τῇ θέσει διαφέροντα. p. 6.	De là (le réservoir d'alimens) dérive le premier caractère des animaux, ou leur cavité intestinale. L'organisation de cette cavité et de ses appartenances a dû varier selon la nature des alimens. P. 21, 22.
In addition to the mouth and stomach, most animals have other common parts by which they exclude the refuse of their food: but in some animals these parts are wanting.	The lowest animals have no other outlet for the refuse of their food, than that by which they admit the food itself.
Μετα δε ταῦτα ἄλλα κοινα μόρια ἔχει τα πγεῖστα των ζώωε πρὸς τούτοις, ᾗ ἀφιησι τὸ περίττωμα της τροφῆς—οὐ γαρ πασιν ὑπάρχει τοῦτο. p. 6.	Il n'y a que les derniers des animaux où les excrémens ressortent par la bouche, et dont l'intestin ait la forme d'un sac sans issue. P. 41.
There are fibres of a peculiar kind in the blood: by the removal of which that fluid is prevented from coagulating: but if they are not removed, it does coagulate. And through defect of these fibres the blood of the deer and of some other animals does not coagulate.	The blood contains a principle called *fibrine;* which, within a short time after the blood has been withdrawn from the body, manifests itself in the form of membranes or filaments.

Aristotle.

Ἔστι δὲ καὶ ἄλλο γένος ἰνῶν, ὃ γίνεται μὲν ἐν αἵματι·—ὧν ἐξαιρουμένων ἐκ τοῦ αἵματος οὐ πήγνυται τὸ αἷμα, ἐὰν δὲ μὴ ἐξαιρεθῶσι, πήγνυται. p. 64. Ἐν μὲν οὖν τῷ τῶν πλείστων αἵματι ζώων ἔνεισιν, ἐν δὲ τῷ τῆς ἐλάφου καὶ προκὸς καὶ βουβαλίδος καὶ ἄλλων τινῶν οὐκ ἔνεισιν ἶνες· διὸ καὶ οὐ πήγνυται αὐτῶν τὸ αἷμα ὁμοίως τοῖς ἄλλοις, ἀλλὰ τὸ μὲν τῶν ἐλάφων παραπλησίως τῷ τῶν δασυπόδων.* p. 65.

Cuvier, tom. I.

(Le fluide nourricier, ou le sang)—contient la fibrine et la gélatine presque toutes disposées à se contracter et à prendre les formes de membranes ou de filamens qui leur sont propres, du moins suffit-il d'un peu de repos pour qu'elles s'y manifestent. P. 27.

The particular senses are five in number, sight, hearing, smell, taste, and touch. Of these the sense of touch is alone common to all animals; and is so generally diffused over the whole body, that it is not said to reside in any specific part. All animals do not possess all the senses; some possess only a part of them. But no animal is without the fifth sense, that of touch.

Εἰσὶ δ' αἱ (αἰσθήσεις) πλεῖσται, καὶ παρ' ἃς οὐδεμία φαίνεται ἴδιος ἑτέρα, πέντε τὸν ἀριθμόν, ὄψις, ἀκοή, ὄσφρησις, γεῦσις, ἁφή. p. 100. Πᾶσι δὲ τοῖς ζῴοις αἴσθησις μία ὑπάρχει κοινὴ μόνη ἡ ἁφή, ὥστε καὶ ἐν ᾧ αὕτη μορίῳ γίνεσθαι πέφυκεν, ἀνώνυμόν ἐστιν. p. 7. Οὐ γὰρ ὁμοίως πᾶσιν ὑπάρχουσιν (αἰσθήσεις,) ἀλλὰ τοῖς μὲν πᾶσαι τοῖς δ' ἐλάττους. p. 100. Τὴν δὲ πέμπτην αἴσθησιν τὴν ἁφὴν καλουμένην—πάντ' ἔχει ζῷα. p. 101.

The most general external sense is that of touch; its seat is the surface of the whole body. Many animals are without the sense of hearing, and of smell, and of sight. Some have none of the senses except that of touch, which is never wanting.

Le sens extérieur le plus général est le toucher; son siège est à la peau, membrane enveloppant le corps entier. P. 36. Beaucoup d'animaux manquent d'oreilles et de narines; plusieurs d'yeux; il y en a qui sont réduits au toucher, lequel ne manque jamais. P. 37.

All animals which draw in and breathe out the air have lungs. Those animals which employ water, analogously to air, in respiration, have gills.

When the element subservient to the process of respiration is the air, the organ of respiration is the lungs: when water, the gills.

* It is deserving of notice, that the animals whose blood is said not to coagulate are such as are usually killed in hunting; and it is understood by physiologists in general, that excessive exercise and violent mental emotions, both which occur in hunted animals, prevent the blood from coagulating. Two of the species here mentioned by Aristotle (πρὸξ and δασύπους or λαγωος) are mentioned by Homer as commonly hunted:

—ἀγίνεσκον νέοι ἄνδρες
Αἶγας ἐπ' ἀγροτέρας, ἠδὲ πρόκας, ἠδὲ λαγωούς. Odyss. p. 295.

Aristotle.

Ὅλως δε πάντα ὅσα τὸν ἀέρα δεχόμενα ἀναπνεῖ καὶ ἐκπνεῖ, πάντ' ἔχει πνεύμονα. p. 43. Τα μεν οὖν ἀνάλογον τῇ ἀναπνοῇ χρώμενα τῷ ὑγρῷ βράγχια ἔχει. p. 215.

Animals in general appear to have a certain degree of intellectual power, and some are capable of instruction. Some animals are cautious; some are cunning. Man alone is capable of meditation and reflection. Many animals possess memory: no animal but man is capable of recollection.

Φαίνονται γαρ (τα ζῷα) ἔχοντά τινα δύναμιν—περί τε φρόνησιν καὶ εὐήθειαν—ἔνια δε κοινωνεῖ τινὸς ἅμα καὶ μαθήσεως καὶ διδασκαλίας. p. 251. Τα μεν φρόνιμα—τα δ' ἐπίβουλα·—Βουλευτικὸν δε μόνον ἄνθρωπός ἐστι των ζώων. καὶ μνήμης μεν καὶ διδαχῆς πολλὰ κοινωνεῖ, ἀναμιμνήσκεσθαι δε οὐδεν ἄλλο δύναται πλὴν ανθρωπος. p. 6.

In the great number of animals there are traces of the moral affections of man; for some are mild and some are fierce. And the same thing may be very readily discerned in children, for in them we may perceive the germs of their future habits; and indeed the dispositions of human beings at that early period of life do not differ from those of the inferior animals.

Ἔνεστι γαρ ἐν τοῖς πλείστοις καὶ των ἄλλων ζῴων ἴχνη των περὶ τὴν ψυχὴν τρόπων, ἅπερ ἐπὶ των ἀνθρώπων ἔχει φανερωτέρας τας διαφοράς. p. 212. Τα

Cuvier, tom. I.

Quand cet élément est de l'air, la surface est creuse, et se nomme *poumon;* quand c'est de l'eau, elle est saillante, et s'appelle *branchie.* P. 43.

Even the most perfect animals are infinitely inferior to man in the intellectual faculties; although it is certain that their intelligence performs similar operations to those of the human mind: and they are capable of instruction. Man has the faculty of associating his general ideas with particular images of a more or less arbitrary character, but easily imprinted in his memory, which serve to recall to him the general ideas which they represent.

Les animaux les plus parfaits sont infiniment au-dessous de l'homme pour les facultés intellectuelles, et il est cependant certain que leur intelligence exécute des opérations du même genre—ils acquièrent par l'expérience une certaine connaissance des choses. P. 51, 52. L'homme a la faculté d'associer ses idées générales à des images particulières et plus ou moins arbitraires, aisées à graver dans la mémoire, et qui lui servent á rappeler les idées générales qu'elles représentent. P. 50.

Animals are susceptible of emulation, and jealousy, &c. In short, we may observe in the higher animals a certain degree of the reasoning faculty, which appears nearly the same with that of infants before they have acquired the power of speech.

Ils sont susceptibles d'émulation et de jalousie—en un mot, on aperçoit dans les animaux supérieurs un certain degré de raisonnement

Aristotle.	*Cuvier*, tom. I.
μεν γάρ ἐστι πρᾶα—τα δε θυμώδη. p. 6. Φανερώτατον δ' ἐστὶ τὸ τοιοῦτον ἐπὶ τὴν των παίδων ἡλικίαν βλέψασιν· ἐν τούτοις γαρ των μεν ὕστερον ἕξεων ἐσομένων ἔστιν ἰδεῖν οἷον ἴχνη καὶ σπέρματα, διαφέρει δ' οὐθεν ὡς εἰπεῖν ἡ ψυχὴ της των θηρίων ψυχῆς κατα τὸν χρόνον τοῦτον. p. 212.	avec tous ses effets bons et mauvais, et qui paraît être à peu près le même que celui des enfans lorsqu'ils n'ont pas encore appris à parler. P. 52.
As man possesses contrivance, and wisdom, and comprehension; so some animals possess a certain natural power, which, though not the same as, in some respects resembles, those faculties.	In a great number of animals there exists a faculty, different from intelligence, which is called *instinct*.
Ὡς γαρ ἐν ἀνθρώπῳ τέχνη καὶ σοφία καὶ σύνεσις, οὕτως ἐνιοις των ζώων ἐστί τις ἑτέρα τοιαύτη φυσικὴ δύναμις. p. 212.	Il existe dans un grand nombre d'animaux une faculté différente de l'intelligence; c'est celle qu'on nomme *instinct*. p. 53.
All animals which have red blood have a spine or backbone: but the other parts of the bony system are wanting in some species, and present in others. The spine is the base or origin of the bony system: it is composed of vertebræ, which are all perforated; and extends from the head to the hips: and the cranium is a continuation of its upper or anterior extremity.	The first general division of animals includes all those which have a spine or backbone consisting of separate portions called vertebræ. The animals of this division are called *vertebrated*. They have all of them red blood: their body is composed of a head, trunk, and members: the spine, which is composed of vertebræ, having each an annular perforation, and moveable upon each other, commences at its upper or anterior extremity from the head; the lower or posterior extremity usually terminating in a tail.
Πάντα δε τὰ ζῷα ὅσα ἔναιμά ἐστιν, ἔχει ῥάχιν—τὰ δ' ἄλλα μόρια τῶν ὀστῶν ἐνίοις μέν ἐστιν, ἐνίοις δ' οὐκ ἔστιν. p. 66. 'Αρχὴ δὲ ἡ ῥάχις ἐστὶν ἐν πᾶσι τοῖς ἔχουσιν ὀστᾶ. σύγκειται δ' ἡ ῥάχις ἐκ σφονδύλων, τείνει δ' ἀπὸ τῆς κεφαλῆς μέχρι πρὸς τὰ ἰσχία. οἱ μὲν οὖν σφόνδυλοι πάντες τετρεμένοι εἰσὶν, ἄνω δὲ τὸ τῆς κεφαλῆς ὀστοῦν συνεχές ἐστι τοῖς ἐσχάτοις σφονδύλοις, ὃ καλεῖται κρανίον. p. 65.	Dans la première de ces formes [générales,] qui est celle de l'homme et des animaux qui lui ressemblent le plus, le cerveau, &c. sont renfermés dans une enveloppe osseuse, qui se compose du crâne et des vertèbres. p. 57. Nous appellerons les animaux de cette forme les *animaux vertébrés*. p. 58. Leur sang est toujours rouge. p. 63. Leur corps se compose toujours de la tête, du tronc et des membres. L'épine est composée de vertèbres

Aristotle.	*Cuvier*, tom. I.
	mobiles les unes sur les autres, dont la première porte la tête, et qui ont toutes une partie annulaire. p. 62, 63. Le plus souvent l'épine se prolonge en une queue. p. 63.
Red-blooded animals when in their perfect state have either no extremities, or they have one or two pair. Those animals which have more than two pair are not red-blooded.	Their extremities never exceed two pair in number: sometimes one pair is wanting, sometimes both.
In some animals the corresponding limbs are different in form, but analogous in use. Thus the anterior extremities of birds are neither hands nor feet, but wings. Fish have no limbs, but appendages, called fins, commonly four in number, sometimes two.	The form of the extremities varies according to the uses to which they are to be applied; the anterior extremities being hands, or feet, or wings, or fins; the posterior, feet or fins.
Τὰ μὲν ἔναιμα τυγχάνει ὄντα—ὅσα ἢ ἄποδά ἐστι τέλεα ὄντα (ἄπουν δὲ φύσει ἐστὶν ἔναιμον πεζὸν τὸ τῶν ὄφεων γένος, p. 10.) ἢ δίποδα ἢ τετράποδα. τὰ δ' ἄναιμα—πάνθ' ὅσα πλέιους πόδας ἔχει τεττάρων. p. 7. Ἔνια δὲ τῶν ζῴων οὔτε εἴδει τὰ μόρια ταὐτὰ ἔχεί οὔτε καθ' ὑπεροχὴν καὶ ἔλλειψιν, ἀλλὰ κατ' ἀναλογίαν. p. 2. Χεῖρας δ' οὐδὲ πόδας προσθίους ἔχει (οἱ ὄρνιθες,) ἀλλὰ πτέρυγας ἴδιον πρὸς τὰ ἄλλα ζῷα. p. 38. Αὐχένα δ' οὐδεὶς ἔχει ἰχθὺς, οὐδὲ κῶλον οὐθὲν—ἴδιον δ' ἔχουσι—τὰ πτερύγια, οἱ μὲν πλεῖστοι τέτταρα, οἱ δὲ προμήκεις δύο. p. 40.	Il n'y a jamais plus de deux paires de membres ; mais elles manquent quelquefois l'une ou l'autre, ou toutes les deux, et prennent des formes relatives aux mouvemens qu'elles doivent exécuter. Les membres antérieurs peuvent être faits en mains, en pieds, en ailes ou en nageoires ; les postérieurs, en pieds ou en nageoires. p. 63.
The red-blooded animals are man, viviparous and oviparous quadrupeds, birds, fish, cetaceous animals, and snakes, &c.	The division of vertebrated animals includes man, the mammalia consisting of viviparous quadrupeds and the cetacea, birds, reptiles of all kinds, many of which, though oviparous, are quadrupeds, and fish.
Ἔστι δὲ ταῦτα (ζῷα ἔναιμα) ἄνθρωπός τε καὶ τὰ ζῳοτόκα τῶν τετραπόδων, ἔτι δὲ καὶ τὰ ᾠοτόκα τῶν τετραπόδων καὶ ὄρνις καὶ ἰχθὺς καὶ κῆτος καὶ—ὄφις. p. 42, 43.	SUBDIVISION DES ANIMAUX VERTEBRES. L'homme—les singes, &c.—les cétacés—les oiseaux—tortues—serpens—poissons. Tom. i. 67.—ii. 351.

Aristotle.

Animals of the largest size are found among those which are red-blooded. All animals which have colourless blood are smaller in size than those which have red blood; with the exception of a few marine animals, as some of the sepiæ.*

Τούτῳ διαφέρει τὰ μέγιστα γένη πρὸς τὰ λοιπὰ τῶν ἄλλων ζώων, τῷ τὰ μὲν ἔναιμα τὰ δ' ἄναιμα εἶναι. p. 42. Πάντα δὲ τὰ ἄναιμα ἐλάττω τὰ μεγέθη ἐστὶ τῶν ἐναίμων ζώων· πλὴν ὀλίγα ἐν τῇ θαλάττῃ μείζονα ἄναιμά ἐστιν, οἷον τῶν μαλακίων ἔνια. p. 9.

Cuvier, tom. I.

Vertebrated animals, all of which have red blood, attain to a much larger size than those whose blood is colourless.

C'est parmi eux (les animaux vertébrés) que se trouvent les plus grands des animaux. p. 62. Le sang est toujours rouge. p. 63.

Aristotle.

All red-blooded animals have the five senses.

Ἄνθρωπος μὲν οὖν—καὶ ὅσα ἔναιμα καὶ ζωοτόκα, πάντα φαίνεται ἔχοντα ταύτας πάσας (αἰσθήσεις.) p. 100.

Cuvier.

Vertebrated animals have always two eyes, two ears, two nostrils, the integuments of the tongue and those of the whole body.

Les sens extérieurs sont toujours deux yeux, deux oreilles, deux narines, les tégumens de la langue, et ceux de la totalité du corps. p. 64.

MAMMALIA.

Aristotle.

No animal which is not viviparous has breasts: and even of viviparous animals those only have them which produce their young alive at once, without the intervention of an egg.

The milk is not, as the blood is, a fluid which animals possess from their birth, but a subsequent secretion; and is contained in the breasts. And all those animals have breasts which are essentially or directly viviparous; as man, and such quadrupeds as are covered with hair; and also cetaceous animals, as the dolphin, the seal, and the whale.

Οὐδὲν τῶν μὴ ζωοτοκούντων (ἔχει μαστούς,) οὐδὲ τὰ ζωοτοκοῦντα πάντα ἀλλ' ὅσα εὐθὺς ἐν αὐτοῖς ζωοτοκεῖ καὶ μὴ

Cuvier.

The animals of the class *mammalia* are essentially viviparous; inasmuch as a direct communication is established between the embryo and the parent immediately after conception.

The new-born offspring is nourished for a time by milk, which is a special and temporary secretion from the mammæ; organs, so exclusively peculiar to this class, as to have determined the distinctive appellation *mammalia*. This class includes all the common viviparous quadrupeds; together with the seal, and the dolphin, and other cetacea.

La génération dans tous les mammifères est essentiellement vivipare; c'est-à-dire que le fœtus,

* See a curious engraving in Montfort, Hist. Nat. des Mollusques, tom. ii. p. 256, epresenting a gigantic sepia grasping a ship and its rigging.

Aristotle.

ᾠοτοκεῖ πρῶτον. p. 40. Τῶν δὲ ὄφεων ὁ μὲν ἔχις ζῳοτοκεῖ ἔξω, ἐν αὑτῷ πρῶτον ᾠοτοκήσας. p. 151. Αἷμα ὕγρον σύμφυτόν ἐστι τοῖς ζῴοις· ὑστερόγενες δὲ καὶ ἀποκοιμένον ἅπασιν, ὅταν ἐνῇ, ἔνεστι, τὸ γάλα·—ἔχει δε, ὅσα ἔχει τὸ γάλα, ἐν τοῖς μαστοῖς. μαστοὺς δ' ἔχει ὅσα ζῳοτοκεῖ καὶ ἐν αὑτοῖς καὶ ἔξω, οἷον ὅσα τε τρίχας ἔχει, ὥσπερ ἄνθρωπος καὶ ἵππος, καὶ τὰ κήτη, οἷον δελφὶς καὶ φώκη και φάλαινα· καὶ γὰρ ταῦτα μαστοῦς ἔχει καὶ γάλα. p. 77.

Cuvier, tom. I.

immédiatement après la conception, descend dans la matrice, enfermé dans ses enveloppes—qui établissent entre lui et sa mère une communication, d'où il tire sa nourriture. p. 75, 76.

Les petits se nourissent pendant quelque temps, après leur naissance, d'une liqueur particulière à cette classe (le lait,) laquelle est produite par les mammelles—qui ont valu à cette classe son nom de mamifères, attendu que lui étant exclusivement propres, elles la distinguent mieux qu'aucun autre caractère extérieur. p. 76. De la classe des mammifères sont l'homme—les singes—le cheval—les phoques—le dauphin—les baleines, &c. p. 79—284.

MAN.

All animals which have limbs resembling those of man, have their legs and thighs and hips sparingly covered with flesh; whereas in man these parts are more fleshy than any other.

The muscles which extend the foot and thigh of man are more powerful than those of any other animal: and hence the calf of the leg is particularly prominent. The part called the pelvis, situate between the hips, is altogether proportionally larger, in man than in any other animal.

Of all animals man has, in proportion to his size, the largest brain; and the smallest interval between his eyes; and the most delicate sense of touch and of taste.

No quadruped has so large a brain as man. His eyes are so placed as to be necessarily directed only forwards. In the delicacy of the sense of taste and touch man excels all other animals.

No animal but man has its breasts in the front of the chest; the elephant, like the human female, has two breasts, but they are placed on the side.

The female breasts are placed in front of the chest.

No animal but man has the faculty of articulate speech; which consists of vowels pronounced by means of the larynx, and of consonants formed by the tongue and

He possesses an advantage peculiar to himself in the organs of voice; for he alone is capable of uttering articulate sounds; a power which apparently depends on the

Aristotle.	*Cuvier*, tom. I.
lips: the dolphin, therefore, which has a voice in consequence of its possessing lungs, and a larynx, cannot articulate, because its tongue is not readily moveable, and it has no lips.	form of his mouth, and the great flexibility of his lips.
Πάντα δὲ τὰ τετράποδα ὀστώδη τὰ σκέλη ἔχει—καὶ ἄσαρκα—ἔστι δὲ καὶ ἀνίσχια—ὁ δὲ ἄνθρωπος τοὐναντίον· σαρκώδη γὰρ ἔχει σχεδὸν μάλιστα τοῦ σώματος τὰ ἰσχία καὶ τοὺς μηροὺς και τὰς κνήμας. p: 29.	Les muscles qui retiennent le pied et la cuisse (de l'homme) dans l'etat d'extension sont plus vigoureux (que ceux d'aucun mammifère); d'où résulte la saillie du mollet et de la fesse—le bassin est plus large. p. 82.
Ἔχει δὲ (ἐγκέφαλον) ἅπαντα ὅσα ἔχει αἷμα—κατὰ μέγεθος δ' ὁμοίως ἔχει ἄνθρωπος πλεῖστον ἐγκέφαλον. p. 19. Τά δ' ὄμματα ἐλαχίστον κατὰ μέγεθος διέστηκεν ἀνθρώπῳ τῶν ζῳων. ἔχει δ' ἀκριβεστάτην ἄνθρωπος τῶν αἰσθήσεων τήν ἁφὴν, δευτέραν δὲ τὴν γεῦσιν. p. 18, 19.	Aucun quadrupède n'approche de lui pour la grandeur et les replis des hémisphères du cerveau. p. 84. Ses deux yeux sont dirigés en avant; il ne voit point de deux côtés à la fois, comme beaucoup de quadrupèdes. La délicatesse de l'odorat doit influer sur celle du goût, et l'homme doit d'ailleurs avoir de l'avantage, á cet égard, au moins sur les animaux dont la langue est revêtue d'écailles; enfin, la finesse de son toucher résulte, et de celle de ses tégumens, &c. p. 85.
Μαστοὺς δ' οὐκ ἔχει οὐθὲν ἐν τῷ πρόσθεν ἀλλ' ἢ ἄνθρωπος· ὁ δ' ἐλέφας ἔχει μεν μαστοὺς δύο, αλλ' οὐκ ἐν τῷ στήθει ἀλλὰ πρός τῷ στήθει. p. 26.	Ses mammelles, au nombre de deux seulement, sont situées sur la poitrine. p. 88.
Τὰ δε ζῳοτόκα καὶ τετράποδα ζῷα ἄλλο ἄλλην ἀφίησι φωνὴν, διάλεκτον δ' οὐδεν ἔχει αλλ' ἴδιον τοῦτ' ἀνθρώπου ἐστίν. (p. 107.) διάλεκτος δ' ἡ τῆς φωνῆς ἐστὶ τῃ γλώττῃ διάρθρωσις. τὰ μεν οὖν φωνήεντα ἡ φωνὴ καὶ ὁ λάρυγξ ἀφίησιν, τὰ δ' ἄφωνα ἡ γλῶττα καὶ τὰ χείλη· ἐξ ὧν ἡ διάλεκτός ἐστιν. p. 105. Ἀφιησι δε καὶ ὁ δελφὶς τριγμὸν καὶ μύζει—ἔστι γὰρ τούτῳ φωνὴ—ἀλλὰ τὴν γλῶτταν οὐκ ἀπολελυμένην (ἔχει) οὐδε χειλη ὥστε ἄρθρον τι τῆς φωνῆς ποιεῖν. p. 106.	L'homme a une prééminence particulière dans les organes de sa voix; il peut seul articuler des sons; la forme de sa bouche et la grande mobilité de ses lèvres en sont probablement les causes. p. 86.

APES, &c.

Aristotle.

The feet of apes are peculiar, and resemble large hands, the toes being like fingers, and the under surface of the hind foot like the palm of the hand, but terminating in a badly shaped heel. Hence they often use their feet as hands. Their arms resemble those of man, as also their hands, and fingers, and nails; and they bend their extremities in the same direction as man does.* The upper part of their body being larger than the lower part, as is the case with decided quadrupeds; and their feet partaking of the character of hands; their pelvis moreover, being small; they are from these joint causes incapable of continuing long in an erect position.

Like man they have two mammæ on the chest; and their internal anatomy resembles the human.

Some of the apes (πίθηκοι) resemble man in many points, as to their face: for they have nostrils and ears; and both their front and back teeth not much unlike those of man.

Οἱ δε πίθηκοι—ἰδίους τοὺς πόδας (ἔχουσι)· εἰσὶ γὰρ οιον χεῖρες μεγάλαι, καὶ οἱ δάκτυλοι ὥσπερ οἱ τῶν χειρῶν, ὁ μέσος μακρότατος, καὶ τὸ κάτω τοῦ ποδὸς χειρὶ ὅμοιον, πλὴν ἐπὶ τὸ μῆκος τὸ τῆς χειρὸς ἐπὶ τὰ ἔσχατα τεῖνον, καθάπερ θέναρ· τοῦτο δε ἐπ' ἄκρου σκληρότερον, κακῶς καὶ ἀμυδρῶς μιμούμενον πτέρνην. κέχρηται δε τοις ποσὶν ἐπ' ἄμφω, καὶ

Cuvier, tom. I.

The hind feet of the quadrumana (to which *order* apes belong) have a thumb capable of being opposed to the other toes, which are as long and as flexible as the fingers; whence they are capable of climbing well; but they do not easily walk or support themselves in an erect position, because their pelvis is narrow, and the plane of the under surface of their feet is not horizontal.

In the character of their intestines, in the direction of their eyes, and in the position of their breasts, they resemble man; and the structure of their fore-arms and hands enables them to imitate us in many of their gestures and actions.

The higher species of apes have flat nails; and teeth very much resembling the human both in number and arrangement, and also in form: and they have no tail.

Les quadrumanes diffèrent de notre espèce par le caractère très-sensible, que ses pieds de derrière ont les pouces libres et opposables aux autres doigts, et que les doigts des pieds sont longs et flexibles comme ceux de la main; aussi toutes les espèces grimpent-elles aux arbres avec facilité, tandis qu'elles

* The same is true of quadrupeds in general: in most of which, however, Aristotle mistook the joint at the heel and wrist, for that of the knee and elbow.

Aristotle.	*Cuvier*, tom. I.
ὡς χερσὶ καὶ ὡς ποσὶ, καὶ συγκάμπτει ὥσπερ χεῖρας.—Ἔχει δε καὶ βραχίονας ὥσπερ ἄνθρωπος, πλὴν δασεῖς· καὶ κάμπτει καὶ τούτους καὶ τὰ σκέλη ὥσπερ ἄνθρωπος—πρὸς δὲ τούτοις χεῖρας καὶ δακτύλους καὶ ὄνυχας ὁμοίους ἀνθρώπῳ, πλὴν πάντα ταῦτα ἐπὶ τὸ θηριωδέστερον. Τὰ δ' ἄνω τοῦ κάτω πολὺ μείζονα ἔχει, ὥσπερ τὰ τετράποδα—καὶ διά τε ταῦτα καὶ διὰ τὸ τοὺς πόδας ἔχειν ὁμοίους χερσὶ—διατελεῖ τὸν πλείω χρόνον τετράπουν ὂν μᾶλλον ἢ ὀρθόν· καὶ οὔτ' ἰσχία ἔχει ὡς τετράπουν ὄν. p. 35, 36.	ne se tiennent et ne marchent debout qu'avec peine, leur pied ne se posant alors que sur le tranchant extérieur, et leur bassin étroit ne favorisant point l'équilibre. p. 100.
Τὰ δ' ἐντὸς διαιρεθέντα ὅμοια ἔχουσιν ἀνθρώπῳ πάντα τὰ τοιαῦτα. p. 36. Ἔχει δ' ἐν τῷ στήθει δύο θηλὰς μαστῶν μικρῶν. p. 35.	Elles ont toutes des intestins assez semblables aux nôtres, les yeux dirigés en avant, les mammelles sur la poitrine. p. 100. La liberté de leurs avant-bras et la complication de leurs mains leur permettent à toutes beaucoup d'actions et de gestes semblables à ceux de l'homme. p. 101.
Τὸ δὲ πρόσωπον ἔχει πολλὰς ὁμοιότητας τῷ τοῦ ἀνθρώπου· καὶ γὰρ μυκτῆρας καὶ ὦτα παραπλήσια ἔχει, καὶ ὀδόντας ὥσπερ ὁ ἄνθρωπος, καὶ τούς προσθίους καὶ τοὺς γομφίους. p. 35.	Les singes—ont á chaque mâchoire quatre dents incisives droites, et à tous les doigts des ongles plats ; deux caractères qui les rapprochent de l'homme plus que les genres suivans ; leurs molaires n'ont aussi, comme les nôtres, que des tubercules mousses. p. 101.

THE HEDGEHOG AND PORCUPINE.

Porcupines and land-echini, or hedgehogs, are covered with spines, which are properly to be considered in these animals as a kind of rigid and indurated hair ; for these spines do not serve the purpose of feet, as they do in sea-echini.	Hedgehogs have their body covered with quills instead of hair ; and so have porcupines.
Τριχῶν γάρ τι εἶδος θετέον καὶ τὰς ἀκανθώδεις τρίχας, οἵας οἱ χερσαῖοι ἔχουσιν ἐχῖνοι καὶ οἱ ὕστριχες· τριχός γὰρ χρείαν παρέχουσιν, ἀλλ' οὐ ποδῶν, ὥσπερ οἱ τῶν θαλαττίων. p. 10.	Les hérissons et les porcépics ont le corps couvert de piquans au lieu de poils. p. 132 et 208.

THE MOLE.

Aristotle.

All viviparous animals have eyes, except the mole; and even this animal, although it has neither the faculty of sight, nor eyes readily visible, cannot be said to be altogether without eyes; for if its skin be taken off, you may distinguish not only the natural situation of the eyes, but that black central part of the eye itself in which the pupil is contained; as if these organs had been imperfectly developed, and the skin had grown over them. If the skin, which is thick, be stripped off from the head, you may perceive on its inner surface, and in the usual region, distinct eyes; which, though small and shrunk, as it were, have all the essential parts of those organs, namely, a pupil placed in the centre of the black part of the eye, and that black part surrounded by the white.*

Ζωοτόκα πάντα (ἔχει ὀφθαλμοὺς) πλὴν ἀσπάλακος. τοῦτον δὲ τρόπον μέν τιν' ἔχειν ἂν θείη τις, ὅλως δ' οὐκ ἔχειν. ὅλως μὲν γὰρ οὔθ' ὁρᾷ οὔτ' ἔχει εἰς τὸ φανερὸν δήλους ὀφθαλμούς· ἀφαιρεθέντος δὲ τοῦ δέρματος ἔχει τήν τε χώραν τῶν ὀμμάτων καὶ τῶν ὀφθαλμῶν τὰ μέλανα κατὰ τὸν τόπον καὶ τὴν χώραν τὴν φύσει τοῖς ὀφθαλμοῖς ὑπάρχουσαν ἐν τῷ ἐκτὸς, ὡς ἐν τῇ γενέσει πηρουμένων καὶ ἐπιφυομένου τοῦ δέρματος. p. 13. 'Αφαιρεθέντος δὲ τοῦ δέρματος ὄντος παχέος ἀπὸ τῆς κεφαλῆς κατὰ τὴν χώραν τὴν ἔξω τῶν ὀμμάτων ἔσωθέν εἰσιν οἱ ὀφθαλμοὶ διεφθαρμένοι, πάντ' ἔχοντες ταὐτά τὰ μέρη τοῖς ἀληψινοίς· ἔχουσι γὰρ τό τε μέλαν καὶ τὸ ἐντὸς τοῦ μέλανος τὴν καλουμένην κόρην, καὶ τὸ κυκλώπιον. p. 100, 101.

Cuvier, tom. I.

The eye of the mole is so small, and so concealed by the skin, that for a long time this animal was supposed to be without eyes. The blind rat-mole has no visible trace of external eyes; but in taking off the skin, a very small black point is observable, which appears to have the organization of an eye, without the possibility of being employed as such, because the skin passes over it not only in an entire state. but as thick and as closely covered with hair as in any other part of the face. This may probably be the animal which, according to M. Olivier, gave the idea to the ancients of describing the mole as totally blind.†

Son œil est si petit, et tellement caché par le poil, qu'on en a nié long-temps l'existence. p. 137. Le rat-taupe aveugle—n'a même point du tout d'œil visible au dehors: mais quand on elève sa peau, on trouve un très-petit point noir qui paraît organisé comme un œil, sans pouvoir servir à la vision, puisque la peau passe dessus sans s'ouvrir ni s'amincir, et sans y avoir moins de poils qu'autre part.—Il se pourrait, comme le dit M. Olivier, qu'il eût donné aux anciens l'idée de fair la taupe toute-à-fait aveugle. p. 201.

* Κυκλώπιον (p. 101.) is evidently synonymous with λευκόν. (p. 12.)

† By an examination of Aristotle's description it is evident that the ancients knew the true state of the case, namely, that the mole has eyes.

THE BEAR.

Aristotle.

The bear is an omnivorous animal, living on various fruits, on honey, on ants, and on flesh; attacking not only the smaller animals, but even wild boars and bulls.* The feet of the bear resemble hands; and for a short time this animal can walk erect on its two hind feet.

Ἡ δ' ἄρκτος παμφάγον ἐστι. καὶ γὰρ καρπὸν ἐσθίει—καί μέλι—καὶ μύρμηκας, καὶ σαρκοφαγεῖ. διὰ γὰρ τὴν ἰσχὺν ἐπιτίθεται οὐ μόνον τοῖς ἐλάφοις ἀλλὰ καὶ τοῖς ἀγρίοις ὑσὶν—καὶ τοῖς ταύροις· ὁμόσε χωρήσασα γὰρ τῷ ταύρῳ κατὰ πρόσωπον ὑπτία καταπίπτει, καὶ τοῦ ταύρου τύπτειν ἐπιχειροῦντος τοῖς μὲν βραχίοσι τὰ κέρατα περιλαμβάνει, τῷ δὲ στόματι τὴν ἀκρωμίαν δακοῦσα καταβάλλει τὸν ταῦρον. βαδίζει δ' ἐπί τινα χρόνον ὀλίγον καὶ τοῖν δυοῖν ποδοῖν ὀρθή. p. 224.

Cuvier, tom. I.

The bear though so powerful an animal is not disposed to feed on flesh, unless when compelled by want of other food. Bears walk on the whole sole of the foot, and are thus enabled to raise themselves with comparative ease in an erect position on their hind feet.

Les ours—malgré leur extrême force, ne mangent-ils guère de chair que par nécessité. Ils marchent sur la plante entière, ce qui leur donne plus de facilité pour se dresser sur leurs pieds de derrière. p. 141.

THE SEAL.

The seal brings forth its young on shore, but passes most of its time in the sea, and derives its nourishment from thence. With respect to its extremities, it may be considered as an imperfect quadruped; for immediately in succession to its shoulder blades it has feet resembling *hands*;† and on each foot are five toes, and each toe has three joints: the hind feet in their shape resemble the tail of a fish. All the teeth of the seal are sharp and pointed, as indicating

The feet of the seal are so short, and so enveloped in the skin, that on land they only serve them for crawling; but, as the interstices of the toes are filled up with membrane, they act as excellent oars; and hence these animals pass the greater part of their life in the sea, only coming to land for the purpose of basking in the sun and suckling their cubs. They have five toes on each of their feet: and on the hind feet the outermost and innermost are longest, the intermediate being

* Its mode of engaging with the bull is thus described by Aristotle: "In engaging the bull, the bear throws itself on its back; and, while the bull is attempting to toss it, the bear takes the bull's horns between its paws, and thus overthrows its adversary."

† From the shortness of the arm and fore-arm in this animal, Aristotle overlooked these parts.

Aristotle.

the approximation of their nature to fish; almost all fish having teeth of that character. The seal has a cloven tongue.

Ἡ δὲ φώκη—τίκτει ἐν τῇ γῇ μὲν—διατρίβει δὲ τοῦ χρόνου τὸν πολὺν καὶ τρέφεται ἐκ τῆς θαλάττης. p. 167, 168. Ἡ δὲ φώκη ὥσπερ πεπηρωμένον ἐστὶ τετράπουν· εὐθύς γὰρ ἔχει μετὰ τὴν ὠμοπλάτην τοὺς πόδας ὁμοίους χερσὶν—πενταδάκτυλοι γάρ εἰσι, καὶ ἕκαστος τῶν δακτύλων καμπὰς ἔχει τρεῖς—οἱ δ' ὀπίσθιοι—τῷ σχήματι παραπλήσιοι ταῖς τῶν ἰχθύων οὐραῖς εἰσί. p. 27. Καρχαρόδουν ἐστὶ πᾶσι τοῖς ὀδοῦσιν, ὡς ἐπαλλάττουσα τῷ γένει τῶν ἰχθύων· οἱ γὰρ ἰχθύες πάντες σχεδὸν καρχαρόδοντές εἰσιν. p. 33. Ἔχει δὲ—ἐσχισμένην τὴν γλῶτταν. p. 48.

Cuvier, tom. I.

shortest. All their teeth have either pointed or cutting edges. Their tongue is indented at the extremity.

Leurs pieds sont si courts, et tellement enveloppés dans la peau, qu'ils ne peuvent, sur terre, leur servir qu'à ramper; mais comme les intervalles des doigts y sont remplis par des membranes, ce sont des rames excellentes; aussi ces animaux passent-ils la plus grande partie de leur vie dans la mer, et ne viennent à terre que pour se reposer au soleil, et allaiter leurs petits. p. 163, 164. Les phoques ont—cinq doigts à tous les pieds—au pieds de derrière, le pouce et le petit doigt sont les plus longs, et les intermédiares les plus courts. Toutes les dents sont tranchantes ou coniques. p. 164 Leur langue est lisse, et échancrée au bout. p. 165.

THE ELEPHANT.

The elephant has five toes on each foot; though the joints of these are not very distinct. It has four teeth on each side of its mouth, with which it triturates its food, and makes it as smooth as bran: and besides these it has two very large teeth. It has a long and powerful proboscis, which it uses as a hand; for with this organ it takes up and conveys to its mouth both solid and liquid food. Its intestines have appendages, presenting the appearance of four stomachs: and it has two mammæ placed by the side of the chest, near the axillæ. The cub of the elephant sucks with its mouth, and not with its proboscis.

Elephants have on each foot five toes, very well defined in the skeleton, but so embedded in the callous skin enveloping the foot that they can only be recognised externally by their nails, which are attached to the edge of this hoof as it were. They have two tusks, which sometimes grow to an enormous size; and either four or eight grinding teeth on each side according to the periods of their developement. The proboscis, terminating in an appendage like a finger, gives to the elephant a degree of address equal to that which the hand of the ape imparts to that animal. The elephant uses this proboscis for the purpose of conveying solid food or pumping up liquids into its mouth. The intestines of the elephant are volumi-

Aristotle.

Ἔστι δὲ πενταδάκτυλον (ὁ ἐλέφας)—τά τε περὶ τοὺς δακτύλους ἀδιαρθρωτότερα ἔχει τῶν ποδῶν. p. 25. Ὁ δ' ἐλέφας οδόντας μὲν ἔχει τέτταρας ἐφ' ἑκάτερα, οἷς κατεργάζεται τὴν τροφὴν (λεαίνει δ' ὥσπερ κριμνὰ,) χωρὶς δὲ τούτων ἄλλους δύο τοὺς μεγάλους. p. 34. Τοῖε δε ἐλὸφασιν ὁ μυκτὴρ γίνεται μακρὸς καὶ ἰσχυρὸς, καὶ χρῆται αὐτῷ ὥσπερ χειρί· προσάγεταί τε γὰρ καὶ λαμβάνει τούτῳ καὶ εἰς τὸ στόμα προσφέρεται τὴν τροφὴν, καί τὴν ὑγρὰν καὶ τὴν ξηρὰν, μόνον τῶν ζῴων. p. 14. Ὁ δε ἐλέφας ἔντερον ἔχει συμφυσεις ἔχον, ὥστε φαίνεσθαι τέτταρας κοιλίας ἔχειν· p. 47. Ἔχει δε τοὺς μαστοὺς δύο περὶ τὰς μασχάλας—οὐκ ἐν τῷ στήθει ἀλλὰ πρὸς τῷ στήθει. p. 30 et 26. Ὁ δε σκὺμνοςὅ ταν γένηται, θηλάζει τῷ στόματι καὶ οὐ τῷ μυκτῆρι. p. 191.

Camper says that in almost all points the anatomy of the elephant is correctly represented by Aristotle; the apparent inconsistencies arising from his having dissected a *young* elephant. Tom. ii. p. 205, &c.

Cuvier, tom. I.

nous; it has two mammæ placed under the breast, and its cub sucks with the mouth, and not with the trunk.

(Les éléphans) ont cinq doigts à tous les pieds, bien complets dans le squelette, mais tellement encroutés dans la peau calleuse qui entoure le pied, qu'ils n'apparaissent au dehors que par les ongles attachés sur le bord de cette espèce de sabot. p. 228, 229. Deux défenses qui sortent de la bouche et prennent souvent un accroissement énorme. p. 229. Tantôt une, tantôt deux mâchelières de chaque côté, quatre ou huit en tout, selon les époques. p. 231. Une trompe cylindrique—terminée par un appendice en forme de doigt—donne à l'éléphant presque autant d'adresse que la perfection de la main peut en donner au singe. Il s'en sert pour saisir tout ce qu'il veut porter à sa bouche et pour pomper sa boisson. p. 229. Les intestins sont très-volumineux—les mammelles, au nombre de deux seulement, placées sous la poitrine. Le petit tette avec la bouche et non avec la trompe. p. 230.

RUMINATING ANIMALS.

All viviparous quadrupeds which have horns are without the front teeth in the upper jaw; and some indeed which have no horns have the same defect with respect to the teeth, as the *camel*.

Of viviparous quadrupeds some are cloven-footed and have hoofs instead of claws, as the ox, sheep, goat, and deer. The same animals have four stomachs, and are said to ruminate.

With the exception of the *camel* and the musk, all the animals of this order have horns; and all are without front teeth in the upper jaw.

The feet terminate in two toes, each of which is covered with a separate hoof, and is opposed to its fellow by a flat surface; from whence they are called cloven-footed. The animals of this order are called *ruminating;* and have always four stomachs.

Aristotle.

With the exception of the deer, all ruminating animals have horns which are partly hollow, and partly solid; the hollow part grows out of the skin, of which it is indeed a continuation; but that part round which this hollow is fitted is solid, and grows out of the bone; as in oxen.

The horns of most animals are, in their form, simple, and are hollow, except at their extremity; the horns of the deer alone are in their form arborescent; and, in their substance, solid throughout.

The deer alone, from the age of two years, sheds its horns annually; the horns of other animals are permanent, unless separated by violence. Deer at the age of one year have merely the rudiments of horns, short sprouts, as it were, covered with downy skin. At the age of two years they develope straight horns like wooden pegs; and are hence called at that period *πατταλίαι*.

At three years their horns have two branches; at four years, more; and in this way the number of branches increases till the animal is six years old; after which the number is not increased.

The horn at first grows as it were in the skin, and has a soft villous covering; and after it has attained its full growth the animal exposes itself to the sun, in order to ripen and dry up this covering.

Τετράποδα ἔναιμα καὶ ζῳοτόκα—ὅσα μὲν ἐστὶ κερατοφόρα, οὐκ ἀμφώδοντά ἐστιν· οὐ γὰρ ἔχει τοὺς προσθίους ἐπὶ τῆς ἄνω σιαγόνος. ἔστι δ' ἔνια οὐκ ἀμφώδοντα καὶ ἀκέρατα, οἷον κάμηλος. p. 32.

Cuvier, tom. I.

The structure of the horns differs in different species. In some the solid osseous part which projects from the frontal bone is covered with a hollow case, which grows over it from the skin, as in oxen, sheep, and goats.

In the various species of deer the osseous projections are covered, during their growth, with skin resembling that of the rest of the head. This skin subsequently perishes, leaving the osseous horn uncovered; and, after a time, the horns themselves are shed; and are succeeded by others which are usually larger than the preceding; and these again are shed in their turn and replaced by others.

The figure of the horn in deer varies according to the age and species of the animal.

Les ruminans—ont l'air d'être presque tous construits sur le même modèle, et les chameaux seuls présentent quelques petites exceptions aux caractères communs. Le premier de ces caractères est de n'avoir d'incisives qu'à la mâchoire inférieure. p. 246. Toute le reste de ruminans (ex-

Aristotle.	*Cuvier*, tom. I.
	cepté les chameaux, &c.) a, au moins dans la sexe mâle, deux cornes, c'est-à-dire, deux proéminences plus ou moins longues des os frontaux. p. 252.
Τῶν δε τετραπόδων καὶ ἐναίμων καὶ ζῳοτόκων τὰ μέν ἐστι—δισχίδῆ, καὶ ἀντὶ τῶν ὀνύχων χηλὰς ἔχει, ὥσπερ πρόβατον καὶ αἲξ καὶ ἔλαφος καὶ βοῦς. p. 29.	Les quatre pieds sont terminés par deux doigts et par deux sabots, qui se regardent par une face aplatie, en sorte qu'ils ont l'air d'un sabot unique, qui aurait été fendu. p. 246.
Καὶ τέτταρας ἔχει ἀνομοίας κοιλίας· ἃ δὴ καὶ λέγεται μηρυκάζειν. p. 46.	Le nom de ruminans indique la propriété singulière de ces animaux, de mâcher une seconde fois les alimens—propriété qui tient à la structure de leurs estomacs. Ils en ont toujours quatre. p. 247.
Τῶν δ' ἐχόντων κέρας δι' ὅλου μὲν ἔχει στερεὸν μόνον ἔλαφος, τὰ δ' ἄλλα κοῖλα μέχρι τινός, τὸ δ' ἔσχατον στερεόν. τὸ μὲν οὖν κοῖλον ἐκ τοῦ δέρματος πέφυκε μᾶλλον. περὶ δὲ [ὃ]* τοῦτο περιήρμόσται τὸ στερεὸν ἐκ τῶν ὀστῶν, οἷον τὰ κέρατα τῶν βοῶν. p. 30. Τῶν δὲ κερὰτων τὰ μὲν πλεῖστα κοῖλά ἐστιν ἀπὸ τῆς προσφύσεως περὶ τὸ ἐντὸς ἐκπεφυκὸς ἐκ τῆς κεφαλῆς ὀστοῦν, ἐπ' ἄκρου δ' ἔχει τὸ στερεὸν, καὶ ἔστιν ἁπλᾶ· τὰ δὲ τῶν ἐλάφων μόνα δι' ὅλου στερεὰ καὶ πολυσχιδῆ. p. 67, 68. 'Αποβάλλει δὲ τὰ κέρατα μόνον ἔλαφος κατ' ἔτος, ἀρξάμενος ἀπὸ διετοῦς, καὶ πάλιν φύει· τὰ δ' ἄλλα συνεχῶς ἔχει, ἐὰν μή τι βίᾳ πηρωθῇ. p. 30. Οἱ μὲν οὖν ἐνιαύσιοι οὐ φύουσι κέρατα, πλὴν ὥσπερ σημείου χάριν ἀρχήν τινα· τοῦτο δ' ἐστὶ βραχὺ καὶ δασύ. φύουσι δὲ διετεῖς πρῶτον τὰ κέρατα εὐθέα, καθάπερ παττάλους· διὸ καὶ καλοῦσι τότε πατταλίας αὐτούς. Τῷ δὲ τρίτῳ ἔτει δίκρουν φύουσι, τῷ δὲ τετάρτῳ τραχύτερον· καὶ τοῦτον τον τρόπον ἀεὶ ἐπιδιδόασι μέχρι ἓξ ἐτῶν. ἀπὸ τούτου δὲ ὅμοια ἀεὶ ἀναφύουσιν. p. 258. Τὰ δὲ κέρατα	Dans le genre des bœufs, &c. les cornes sont revêtues d'un étui—on donne en particulier le nom de *corne* à la substance de cet étui, et lui-même porte celui de *corne creuse*. p. 252. Dans le genre des cerfs, les proéminences couvertes pendant un temps d'une peau velue comme celle du reste de la tête, ont à leur base un anneau de tubercules osseux, qui, en grossissant, compriment et oblitèrent les vaisseaux nourrissiers de cette peau. Elle se dessèche et est enlevée; la proéminence osseuse mise à nu, se sépare au bout de quelque temps du crâne auquel elle tenait; elle tombe, et l'animal demeure sans armes. Mais il lui en repousse bientôt de nouvelles, d'ordinaire plus grandes que les précédentes, et destinées à subir les mêmes révolutions. Ces cornes, purement osseuses, et sujettes à des changemens périodiques, portent le nom de *bois*. p. 253. La

* There can be no doubt from the structure of the horns of oxen, &c. that the relative (ὃ) ought to be retained; and the τὸ κοῖλον ἐκ τοῦ δέρματος is evidently opposed to the τὸ στερεὸν ἐκ τῶν ὀστῶν. But the question is quite settled by the following passage from p. 67, τῶν δὲ κεράτων, κ. τ. λ.

Aristotle.	*Cuvier*, tom. I.
φύεται ὥσπερ ἐν δέρματι τὸ πρῶτον, καὶ γίνονται δασέα· ὅταν δ' αὐξηθῶσιν, ἡλιάζονται, ἵν' ἐκπέψωσι καὶ ξηράνωσι τὸ κέρας. p. 259.	figure de ce *bois* varie beaucoup—selon l'âge. p. 254.

CETACEOUS ANIMALS.

The dolphin and whale and other cetaceous animals, which have not gills, but a tube for conveying away the sea-water received into their mouth, are viviparous; and they respire air, for they have lungs: and hence, if caught in a net, and unable to come to the surface for the purpose of breathing, they are suffocated.	Cetaceous animals remain constantly in the water; but, as they respire by means of lungs, they are obliged to come often to the surface for air. p. 272. The ordinary cetacea possess a remarkable apparatus, from which they are called *blowers*, by means of which they discharge through their nostrils a large volume of water which they take into their mouth with their food. p. 275.
The dolphin utters a kind of murmur when it is in the air; for it has a voice, inasmuch as it has lungs, and an air-tube leading to them; but having no lips, and its tongue being not sufficiently moveable, it is unable to utter an articulate sound.	They have no prominent laminæ in their glottis; and hence their voice is nothing more than a simple lowing. p. 276.
The dolphin has mammæ, not placed in the anterior part of the body, but near the vent.	Their mammæ are placed near the vent. p. 276.
The mildness and docility of the dolphin are remarkable.	The general organization of the dolphin's brain shows that it possesses the docility usually attributed to it. p. 278.
These fish swim in large flocks, and their swiftness is so remarkable that they have been known to spring over the decks of ships.	The common dolphin, which is found in large flocks in every sea, and is remarkable for its swiftness of motion, so that it occasionally darts over the decks of ships, appears evidently to be the dolphin of the ancients. p. 278.
The cetaceous animal called mysticetus has no teeth, but hairs instead, like hogs' bristles.	The upper jaw of the balænæ is furnished with thin transverse laminæ closely set, formed of a kind of fibrous horn terminating in a bristly fringe at the border. p. 284.

Aristotle.	*Cuvier*, tom. I.
Δελφὶς δὲ καὶ φάλαινα καὶ τὰ ἄλλα κήτη, ὅσα μὴ ἔχει βράγχια ἀλλὰ φυσητῆρα, ζῳοτοκοῦσιν. Ἀναπνεῖ δὲ πάντα ὅσα ἔχει φυσητῆρα, καὶ δέχεται τὸν ἀέρα· πλευμονα γὰρ ἔχουσιν. p. 167. Διὸ καὶ λαμβανόμενος ὁ δελφὶς ἐν τοῖς δικτύοις ἀποπνίγεται ταχέως διὰ τὸ μὴ ἀναπνεῖν. p. 215.	Les cétacés se tiennent constamment dans les eaux ; mais comme ils respirent par des poumons, ils sont obligés de revenir souvent à la surface pour y prendre de l'air. p. 272. Les cétacés ordinaires se distinguent par l'appareil singulier qui leur a valu le nom commun de *souffleurs.* C'est qu'engloutissant, avec leur proie, de grands volumes d'eau, il leur fallait une voie pour s'en débarrasser; elle s'amasse dans un sac placé à l'orifice extérieur de la cavité du nez, d'ou elle est chassée avec violence—au travers d'une ouverture percée au-dessus de la tête. p. 275, 276.
Ἀφίησι δὲ καὶ ὁ δελφὶς τριγμὸν καὶ μύζει, ὅταν ἐξέλθῃ, ἐν τῷ ἀέρι—ἔστι γὰρ τούτῳ φωνή· ἔχει γὰρ καὶ πλεύμονα καὶ ἀρτηρίαν, ἀλλὰ τὴν γλῶτταν οὐκ ἀπολελυμένην οὐδὲ χείλη ὥστε ἄρθρον τι τῆς φωνῆς ποιεῖν. p. 106.	Il n'y a point de lames saillantes dans leur glotte, et leur voix doit se réduire à de simples mugissemens. p. 276.
Ὁ δελφὶς ἔχει μαστοὺς δύο, οὐκ ἄνω δ' ἀλλὰ πλησίον τῶν ἄρθρων. p. 40.	Leurs mamelles sont près de l'anus. p. 276.
Τῶν δὲ θαλασσίων πλεῖστα λέγεται σημεῖα περὶ τοὺς δελφῖνας πραότητος καὶ ἡμερότητος. p. 301.	Toute l'organisation de son cerveau annonce que le dauphin ne doit pas être dépourvu de la docilité que les anciens lui attribuaient. p. 278.
Ἤδη δ' ὦπται δελφίνων μεγάλων ἀγέλη ἅμα καὶ μικρῶν. Λέγεται δὲ καὶ περὶ ταχυτῆτος ἄπιστα τοῦ ζῴου· ἁπάντων γὰρ δοκεῖ εἶναι ζῴων τάχιστον, καὶ τῶν ἐνύδρων καὶ τῶν χερσαίων, καὶ ὑπεράλλονται δὲ πλοίων μεγάλων ἱστούς. p. 302.	Cet animal, répandu en grandes troupes dans toutes les mers, et célèbre par la vélocité de son mouvement, qui le fait s'élancer quelquefois sur le tillâc des navires, paraît réellement avoir été le dauphin des anciens. p. 278.
Ἔτι δὲ καὶ ὁ μῦς τὸ κῆτος ὀδόντας μὲν ἐν τῷ στόματι οὐκ ἔχει, τρίχας δὲ ὁμοίας ὑείαις. p. 72.	La mâchoire supérieure—a ses deux côtés garnis de lames transverses minces et serrées,—formées d'une espèce de corne fibreuse, effilées à leur bord. p. 284.

From the preceding comparison it appears that, with respect to those points in the history of animals, the knowledge of which was equally accessible to both writers, the descriptions of Aristotle are hardly inferior in accuracy to those of Cuvier. Nor does this observation hold with

reference to the more common animals only: it is equally remarkable with reference to those which are of comparative rarity; in support of which assertion I would refer, among other instances, to the description of the sepia, and of the chameleon, and of the evolutiou of the egg of the bird during incubation. But I have perhaps already extended this comparison too far, and will therefore here conclude.

THE END.

*

THE BRIDGEWATER TREATISES

ON THE

POWER, WISDOM, AND GOODNESS OF GOD, AS MANIFESTED IN THE CREATION.

TREATISE III.

ON ASTRONOMY AND GENERAL PHYSICS.

BY THE REV. W. WHEWELL.

ET HÆC DE DEO, DE QUO UTIQUE EX PHÆNOMENIS DISSERERE AD PHILOSOPHIAM NATURALEM PERTINET.

NEWTON, CONCLUSION OF THE PRINCIPIA.

ASTRONOMY

AND

GENERAL PHYSICS,

CONSIDERED

WITH REFERENCE TO NATURAL THEOLOGY.

BY THE

REV. WILLIAM WHEWELL, M.A.

FELLOW AND TUTOR OF TRINITY COLLEGE, CAMBRIDGE.

A NEW EDITION.

PHILADELPHIA:

CAREY, LEA & BLANCHARD.

1836.

TO THE

RIGHT HONOURABLE AND RIGHT REVEREND

CHARLES JAMES,

LORD BISHOP OF LONDON.

MY LORD,

I OWE it to you that I was selected for the task attempted in the following pages, a distinction which I feel to be honourable; and on this account alone I should have a peculiar pleasure in dedicating the work to your lordship. I do so with additional gratification on another account: the treatise has been written within the walls of the college of which your lordship was formerly a resident member, and its merits, if it have any, are mainly due to the spirit and habits of the place. The society is always pleased and proud to recollect that a person of the eminent talents and high character of your lordship is one of its members; and I am persuaded that any effort in the cause of letters and religion coming from that quarter, will have for you an interest beyond what it would otherwise possess.

The subject proposed to me was limited: my prescribed object is to lead the friends of religion to look with confidence and pleasure on the progress of the physical sciences, by showing how admirably every advance in our knowledge of the universe harmonizes with the belief of a most wise and good God. To do this effectually may be, I trust, a useful labour. Yet, I feel most deeply, what I would take this occasion to express, that this and all that the speculator concerning Natural Theology can do, is utterly insufficient for the great ends of religion; namely, for the purpose of reforming men's lives, of purifying and elevating their characters, of preparing them for a more exalted state of being. It is the need of something fitted to do this, which gives to religion its vast

and incomparable importance; and this can, I well know, be achieved only by that Revealed Religion of which we are ministers, but on which the plan of the present work did not allow me to dwell.

That Divine Providence may prosper the labours of your lordship, and of all who are joined with you in the task of maintaining and promoting *this* Religion, is, my lord, the earnest wish and prayer of

Your very faithful

and much obliged servant,

WILLIAM WHEWELL.

Trinity College, Cambridge,
Feb. 25, 1833.

NOTICE.

The series of Treatises, of which the present is one, is published under the following circumstances :

The Right Honourable and Reverend Francis Henry, Earl of Bridgewater, died in the month of February, 1829 ; and by his last Will and Testament, bearing date the 25th of February, 1825, he directed certain Trustees therein named to invest in the public funds the sum of Eight thousand pounds sterling; this sum, with the accruing dividends thereon, to be held at the disposal of the President, for the time being, of the Royal Society of London, to be paid to the person or persons nominated by him. The Testator further directed, that the person or persons selected by the said President should be appointed to write, print, and publish one thousand copies of a work *On the Power, Wisdom, and Goodness of God, as manifested in the Creation; illustrating such work by all reasonable arguments, as for instance the variety and formation of God's creatures in the animal, vegetable, and mineral kingdoms; the effect of digestion, and thereby of conversion; the construction of the hand of man, and an infinite variety of other arguments; as also by discoveries ancient and modern, in arts, sciences, and the whole extent of literature.* He desired, moreover, that the profits arising from the sale of the works so published should be paid to the authors of the works.

The late President of the Royal Society, Davies Gilbert, Esq. requested the assistance of his Grace the Archbishop of Canterbury and of the Bishop of London, in determining upon the best mode of carrying into effect the intentions of the Testator. Acting with their advice, and with the concurrence of a nobleman immediately connected with the deceased, Mr. Davies Gilbert appointed the following eight gentlemen to write separate Treatises on the different branches of the subject, as here stated :

THE REV. THOMAS CHALMERS, D. D.

PROFESSOR OF DIVINITY IN THE UNIVERSITY OF EDINBURGH.

ON THE ADAPTATION OF EXTERNAL NATURE TO THE MORAL AND INTELLECTUAL CONSTITUTION OF MAN.

JOHN KIDD, M. D. F. R. S.

REGIUS PROFESSOR OF MEDICINE IN THE UNIVERSITY OF OXFORD.

ON THE ADAPTATION OF EXTERNAL NATURE TO THE PHYSICAL CONDITION OF MAN.

THE REV. WILLIAM WHEWELL, M. A. F. R. S.

FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

ON ASTRONOMY AND GENERAL PHYSICS.

SIR CHARLES BELL, K. H. F. R. S.

THE HAND: ITS MECHANISM AND VITAL ENDOWMENTS AS EVINCING DESIGN.

PETER MARK ROGET, M. D.

FELLOW OF AND SECRETARY TO THE ROYAL SOCIETY.

ON ANIMAL AND VEGETABLE PHYSIOLOGY.

THE REV. WILLIAM BUCKLAND, D. D. F. R. S.

CANON OF CHRIST CHURCH, AND PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF OXFORD.

ON GEOLOGY AND MINERALOGY.

THE REV. WILLIAM KIRBY, M. A. F. R. S.

ON THE HISTORY, HABITS, AND INSTINCTS OF ANIMALS.

WILLIAM PROUT, M. D. F. R. S.

ON CHEMISTRY, METEOROLOGY, AND THE FUNCTION OF DIGESTION.

His Royal Highness the Duke of Sussex, President of the Royal Society, having desired that no unnecessary delay should take place in the publication of the above-mentioned treatises, they will appear at short intervals, as they are ready for publication.

CONTENTS.

[Within the last year or two, several works have been published in this Country on subjects more or less closely approaching to that here treated. It may, therefore, be not superfluous to say that the Author of the following pages believes that he has not borrowed any of his views or illustrations from recent English writers on Natural Theology.]

ON

ASTRONOMY AND GENERAL PHYSICS.

INTRODUCTION.

CHAPTER I.

OBJECT OF THE PRESENT TREATISE.

The examination of the material world brings before us a number of things and relations of things which suggest to most minds the belief of a creating and presiding Intelligence. And this impression, which arises with the most vague and superficial consideration of the objects by which we are surrounded, is, we conceive, confirmed and expanded by a more exact and profound study of external nature. Many works have been written at different times with the view of showing how our knowledge of the elements and their operation, of plants and animals and their construction, may serve to nourish and unfold our idea of a Creator and Governor of the world. But though this is the case, a new work on the same subject may still have its use. Our views of the Creator and Governor of the world, as collected from or combined with our views of the world itself, undergo modifications, as we are all led by new discoveries, new generalizations, to regard nature in a new light. The conceptions concerning the Deity, his mode of effecting his purposes, the scheme of his government, which are suggested by one stage of our knowledge of natural objects and operations, may become manifestly imperfect or incongruous, if adhered to and applied at a later period, when our acquaintance with the immediate causes of natural events has been greatly extended. On this account it may be interesting, after such an advance, to show how the views of the creation, preservation, and government of the universe, which natural science opens to us, harmonize with our belief in a Creator, Governor, and Preserver of the world. To do this with respect to certain depart-

ments of Natural Philosophy is the object of the following pages; and the author will deem himself fortunate, if he succeeds in removing any of the difficulties and obscurities which prevail in men's minds, from the want of a clear mutual understanding between the religious and the scientific speculator. It is needless here to remark the necessarily imperfect and scanty character of Natural Religion; for most persons will allow that, however imperfect may be the knowledge of a Supreme Intelligence which we gather from the contemplation of the natural world, it is still of most essential use and value. And our purpose on this occasion is, not to show that Natural Theology is a perfect and satisfactory scheme, but to bring up our Natural Theology to the point of view in which it may be contemplated by the aid of our Natural Philosophy.

Now the peculiar point of view which at present belongs to Natural Philosophy, and especially to the departments of it which have been most successfully cultivated, is,' that nature, so far as it is an object of scientific research, is a collection of facts governed by *laws:* our knowledge of nature is our knowledge of laws; of laws of operation and connexion, of laws of succession and co-existence, among the various elements and appearances around us. And it must therefore here be our aim to show how this view of the universe falls in with our conception of the Divine Author, by whom we hold the universe to be made and governed.

Nature acts by general laws; that is, the occurrences of the world in which we find ourselves, result from causes which operate according to fixed and constant rules. The succession of days, and seasons, and years, is produced by the motions of the earth; and these again are governed by the attraction of the sun, a force which acts with undeviating steadiness and regularity. The changes of winds and skies, seemingly so capricious and casual, are produced by the operation of the sun's heat upon air and moisture, land and sea; and though in this case we cannot trace the particular events to their general causes, as we can trace the motions of the sun and moon, no philosophical mind will doubt the generality and fixity of the rules by which these causes act. The variety of the effects takes place, because the circumstances in different cases vary; and not because the action of the material causes leaves anything to chance in the result. And again, though the vital movements which go on in the frame of vegetables and animals depend on agencies still less known, and probably still more complex, than those which rule the weather, each of the powers on which such movements depend has its peculiar laws of action, and these are as universal and as invariable as the law by which a stone falls to the earth when not supported.

The world then is governed by general laws; and in order to collect from the world itself a judgment concerning the nature and character of its government, we must consider the import and tendency of such laws, so far as they come under our knowledge. If

there be, in the administration of the universe, intelligence and benevolence, superintendence and foresight, grounds for love and hope, such qualities may be expected to appear in the constitution and combination of those fundamental regulations by which the course of nature is brought about, and made to be what it is.

If a man were, by some extraordinary event, to find himself in a remote and unknown country, so entirely strange to him that he did not know whether there existed in it any law or government at all; he might in no long time ascertain whether the inhabitants were controlled by any superintending authority; and with a little attention he might determine also whether such authority were exercised with a prudent care for the happiness and well-being of its subjects, or without any regard and fitness to such ends; whether the country were governed by laws at all, and whether the laws were good. And according to the laws which he thus found prevailing, he would judge of the sagacity, and of the purposes of the legislative power.

By observing the laws of the material universe and their operation, we may hope, in a somewhat similar manner, to be able to direct our judgment concerning the government of the universe: concerning the mode in which the elements are regulated and controlled, their effects combined and balanced. And the general tendency of the results thus produced may discover to us something of the character of the power which has legislated for the material world.

We are not to push too far the analogy thus suggested. There is undoubtedly a wide difference between the circumstances of man legislating for man, and God legislating for matter. Still we shall, it will appear, find abundant reason to admire the wisdom and the goodness which have established *Laws of Nature*, however rigorously we may scrutinize the import of this expression.

CHAPTER II.

ON LAWS OF NATURE.

When we speak of material nature as being governed by *laws*, it is sufficiently evident that we use the term in a manner somewhat metaphorical. The laws to which man's attention is primarily directed are *moral* laws; rules laid down for his actions; rules for the conscious actions of a person; rules which, as a matter of possibility, he may obey or may transgress; the latter event being combined, not with an impossibility, but with a penalty. But the *Laws of Nature* are something different from this; they are rules for that

which *things* are to do and suffer; and this by no consciousness or will of theirs. They are rules describing the mode in which things *do* act; they are invariably obeyed; their transgression is not punished, it is excluded. The language of a moral law is, man *shall* not kill; the language of a Law of Nature is, a stone *will* fall to the earth.

The two kinds of law direct the actions of persons and of things, by the sort of control of which persons and things are respectively susceptible; so that the metaphor is very simple; but it is proper for us to recollect that it is a metaphor, in order that we may clearly apprehend what is implied in speaking of the Laws of Nature.

In this phrase are included all properties of the portions of the material world; all modes of action and rules of causation, according to which they operate on each other. The whole course of the visible universe therefore is but the collective result of such laws; its movements are only the aggregate of *their* working. All natural occurrences, in the skies and on the earth, in the organic and in the inorganic world, are determined by the relations of the elements and the actions of the forces of which the rules are thus prescribed.

The relations and rules by which these occurrences are thus determined necessarily depend on measures of time and space, motion and force; on quantities which are subject to numerical measurement, and capable of being connected by mathematical properties. And thus all things are ordered by number and weight and measure. "God," as was said by the ancients, "works by geometry:" the legislation of the material universe is necessarily delivered in the language of mathematics; the stars in their courses are regulated by the properties of conic sections, and the winds depend on arithmetical and geometrical progressions of elasticity and pressure.

The constitution of the universe, so far as it can be clearly apprehended by our intellect, thus assumes a shape involving an assemblage of mathematical propositions: certain algebraical formulæ, and the knowledge when and how to apply them, constitute the last step of the physical science to which we can attain. The labour and the endowments of ages have been employed in bringing such science into the condition in which it now exists; and an exact and extensive discipline in mathematics, followed by a practical and profound study of the researches of natural philosophers, can alone put any one in possession of all the knowledge concerning the course of the material world, which is at present open to man. The general impression, however, which arises from the view thus obtained of the universe, the results which we collect from the most careful scrutiny of its administration, may, we trust, be rendered intelligible without this technical and laborious study, and to do this is our present object.

It will be our business to show that the laws which really prevail in nature are, by their *form*, that is, by the nature of the connexion which they establish among the quantities and properties which they

regulate, remarkably adapted to the office which is assigned them; and thus offer evidence of selection, design, and goodness, in the power by which they were established. But these characters of the legislation of the universe may also be seen, in many instances, in a manner somewhat different from the selection of the law. The *nature of the connexion* remaining the same, the quantities which it regulates may also in their *magnitude* bear marks of selection and purpose. For the law may be the same while the quantities to which it applies are different. The law of the gravity which acts to the earth and to Jupiter, is the same; but the intensity of the force at the surfaces of the two planets is different. The law which regulates the density of the air at any point, with reference to the height from the earth's surface, would be the same, if the atmosphere were ten times as large, or only one tenth as large as it is; if the barometer at the earth's surface stood at three inches only, or if it showed a pressure of thirty feet of mercury.

Now this being understood, the adaptation of a law to its purpose, or to other laws, may appear in two ways:—either in the form of the law, or in the amount of the magnitudes which it regulates, which are sometimes called *arbitrary magnitudes.*

If the attraction of the sun upon the planets did not vary inversely as the square of the distance, the *form* of the law of gravitation would be changed; if this attraction were, at the earth's orbit, of a different *value* from its present one, the arbitrary magnitude would be changed; and it will appear, in a subsequent part of this work, that either change would, so far as we can trace its consequences, be detrimental. The form of the law determines in what manner the facts shall take place; the arbitrary magnitude determines how fast, how far, how soon; the one gives a model, the other a measure of the phenomenon; the one draws the plan, the other gives the scale on which it is to be executed; the one gives the rule, the other the rate. If either were wrongly taken, the result would be wrong too.

CHAPTER III.

MUTUAL ADAPTATION IN THE LAWS OF NATURE.

To ascertain such laws of nature as we have been describing, is the peculiar business of science. It is only with regard to a very small portion of the appearances of the universe, that science, in any strict application of the term, exists. In very few departments of research have men been able to trace a multitude of known facts to

causes which appear to be the ultimate material causes, or to discern the laws which seem to be the most general laws. Yet, in one or two instances, they have done this, or something approaching to this; and most especially in the instance of that part of nature, which it is the object of this treatise more peculiarly to consider.

The apparent motions of the sun, moon, and stars have been more completely reduced to their causes and laws than any other class of phenomena. Astronomy, the science which treats of these, is already a wonderful example of the degree of such knowledge which man may attain. The forms of its most important laws may be conceived to be certainly known; and hundreds of observers in all parts of the world are daily employed in determining, with additional accuracy, the arbitrary magnitudes which these laws involve.

The inquiries in which the mutual effects of heat, moisture, air, and the like elements are treated of, including, among other subjects, all that we know of the causes of the weather (meteorology) is a far more imperfect science than astronomy. Yet, with regard to these agents, a great number of laws of nature have been discovered, though, undoubtedly, a far greater number remain still unknown.

So far, therefore, as our knowledge goes, astronomy and meteorology are parts of natural philosophy in which we may study the order of nature with such views as we have suggested; in which we may hope to make out the adaptations and aims which exist in the laws of nature; and thus to obtain some light on the tendency of this part of the legislation of the universe, and on the character and disposition of the Legislator.

The number and variety of the laws which we find established in the universe is so great, that it would be idle to endeavour to enumerate them. In their operation they are combined and intermixed in incalculable and endless complexity, influencing and modifying each other's effects in every direction. If we attempt to comprehend at once the whole of this complex system, we find ourselves utterly baffled and overwhelmed by its extent and multiplicity. Yet, in so far as we consider the bearing of one part upon another, we receive an impression of adaptation, of mutual fitness, of conspiring means, of preparation and completion, of purpose and provision. This impression is suggested by the contemplation of every part of nature; but the grounds of it, from the very circumstances of the case, cannot be conveyed in a few words. It can only be fully educed by leading the reader through several views and details, and must grow out of the combined influence of these on a sober and reflecting frame of mind. However strong and solemn be the conviction which may be derived from a contemplation of nature, concerning the existence, the power, the wisdom, the goodness of our Divine Governor, we cannot expect that this conviction, as resulting from the extremely complex spectacle of the material world, should

be capable of being irresistibly conveyed by a few steps of reasoning, like the conclusion of a geometrical proposition, or the result of an arithmetical calculation.

We shall, therefore, endeavour to point out cases and circumstances in which the different parts of the universe exhibit this mutual adaptation, and thus to bring before the mind of the reader the evidence of wisdom and providence, which the external world affords. When we have illustrated the correspondences which exist in every province of nature, between the qualities of brute matter and the constitution of living things, between the tendency to derangement and the conservative influences by which such a tendency is counteracted, between the office of the minutest speck and of the most general laws; it will, we trust, be difficult or impossible to exclude from our conception of this wonderful system, the idea of a harmonizing, a preserving, a contriving, an intending Mind; of a Wisdom, Power, and Goodness far exceeding the limits of our thoughts.

CHAPTER IV.

DIVISION OF THE SUBJECT.

In making a survey of the universe, for the purpose of pointing out such correspondences and adaptations as we have mentioned, we shall suppose the general leading facts of the course of nature to be known, and the explanations of their causes now generally established among astronomers and natural philosophers to be conceded. We shall assume therefore that the earth is a solid globe of ascertained magnitude, which travels round the sun, in an orbit nearly circular, in a period of about three hundred and sixty-five days and a quarter, and in the mean time revolves, in an inclined position, upon its own axis in about twenty-four hours, thus producing the succession of appearances and effects which constitute seasons and climates, day and night;—that this globe has its surface furrowed and ridged with various inequalities, the waters of the ocean occupying the depressed parts:—that it is surrounded by an atmosphere, or spherical covering of air; and that various other physical agents, moisture, electricity, magnetism, light, operate at the surface of the earth, according to their peculiar laws. This surface is, as we know, clothed with a covering of plants, and inhabited by the various tribes of animals, with all their variety of sensations, wants, and enjoyments. The relations and connexions of the larger portions of the world, the sun, the planets, and the

stars, the *cosmical* arrangements of the system, as they are sometimes called, determine the course of events among these bodies; and the more remarkable features of these arrangements are therefore some of the subjects for our consideration. These cosmical arrangements, in their consequences, affect also the physical agencies which are at work at the surface of the earth, and hence come in contact with *terrestrial* occurrences. They thus influence the functions of plants and animals. The circumstances in the cosmical system of the universe, and in the organic system of the earth, which have thus a bearing on each other, form another of the subjects of which we shall treat. The former class of considerations attends principally to the stability and other apparent perfections of the solar systems; the latter to the well-being of the system of organic life by which the earth is occupied. The two portions of the subject may be treated as Cosmical Arrangements and Terrestrial Adaptations.

We shall begin with the latter class of adaptations, because in treating of these the facts are more familiar and tangible, and the reasonings less abstract and technical, than in the other division of the subject. Moreover, as in this case men have no difficulty in recognising as desirable the end which is answered by such adaptations, and they therefore the more readily consider it *as an end*. The nourishment, the enjoyment, the diffusion of living things, are willingly acknowledged to be a suitable object for contrivance; the simplicity, the permanence, of an inert mechanical combination might not so readily be allowed to be a manifestly worthy aim of a Creating Wisdom. The former branch of our argument may therefore be best suited to introduce to us the Deity as the institutor of Laws of Nature, though the latter may afterwards give us a wider view and a clearer insight into one province of his legislation.

BOOK I.

TERRESTRIAL ADAPTATIONS.

We proceed in this Book to point out relations which subsist between the laws of the inorganic world, that is, the general facts of astronomy and meteorology; and the laws which prevail in the organic world, the properties of plants and animals.

With regard to the first kind of laws, they are in the highest degree various and unlike each other. The intensity and activity of natural influences follow in different cases the most different rules. In some instances they are *periodical*, increasing and diminishing alternately, in a perpetual succession of equal intervals of time. This is the case with the heat at the earth's surface, which has a period of a year; with the light, which has a period of a day. Other qualities are *constant*, thus the force of gravity at the same place is always the same. In some cases, a very simple cause produces very complicated effects; thus the globular form of the earth, and the inclination of its axis during its annual motion, give rise to all the variety of climates. In other cases a very complex and variable system of causes produces effects comparatively steady and uniform; thus solar and terrestrial heat, air, moisture, and probably many other apparently conflicting agents, join to produce our weather, which never deviates very far from a certain average standard.

Now a general fact, which we shall endeavour to exemplify in the following chapters, is this:—That those properties of plants and animals which have reference to agencies of a periodical character, have also by their nature a periodical mode of working; while those properties which refer to agencies of constant intensity, are adjusted to this constant intensity: and again, there are peculiarities in the nature of organized beings which have reference to a variety in the conditions of the external world, as, for instance, the difference of the organized population of different regions: and there are other peculiarities which have a reference to the constancy of the average of such conditions, and the limited range of the deviations from that average; as for example, that constitution by which each plant and animal is fitted to exist and prosper in its usual place in the world.

And not only is there this general agreement between the nature of the laws which govern the organic and inorganic world, but also

there is a coincidence between the *arbitrary magnitudes* which such laws involve on the one hand and on the other. Plants and animals have, in their construction, certain periodical functions, which have a reference to alternations of heat and cold; the length of the period which belongs to these functions by their construction, appears to be that of the period which belongs to the actual alternations of heat and cold, namely, a year. Plants and animals have again in their construction certain other periodical functions, which have a reference to alternations of light and darkness; the length of the period of such functions appears to coincide with the natural day. In like manner the other arbitrary magnitudes which enter into the laws of gravity, of the effects of air and moisture, and of other causes of permanence, and of change, by which the influences of the elements operate, are the same arbitrary magnitudes to which the members of the organic world are adapted by the various peculiarities of their construction.

The illustration of this view will be pursued in the succeeding chapters; and when the coincidence here spoken of is distinctly brought before the reader, it will, we trust, be found to convey the conviction of a wise and benevolent design, which has been exercised in producing such an agreement between the internal constitution and the external circumstances of organized beings. We shall adduce cases where there is an apparent relation between the course of operation of the elements and the course of vital functions; between some fixed measure of time or space, traced in the lifeless and in the living world; where creatures are constructed on a certain plan, or a certain scale, and this plan or this scale is exactly the single one which is suited to their place on the earth; where it was necessary for the Creator (if we may use such a mode of speaking) *to take account* of the weight of the earth, or the density of the air, or the measure of the ocean, and where these quantities are rightly taken account of in the arrangements of creation. In such cases we conceive that we trace a Creator, who, in producing one part of his work, was not forgetful or careless of another part; who did not cast his living creatures into the world to prosper or perish as they might find it suited to them or not; but fitted together, with the nicest skill, the world and the constitution which he gave to its inhabitants; so fashioning it and them, that light and darkness, sun and air, moist and dry, should become their ministers and benefactors, the unwearied and unfailing causes of their well-being.

We have spoken of the mutual adaptation of the organic and the inorganic world. If we were to conceive the contrivance of the world as taking place in an order of time in the contriving mind, we might also have to conceive this adaptation as taking place in one of two ways: we might either suppose the laws of inert nature to be accommodated to the foreseen wants of living things, or the organization of life to be accommodated to the previously established

laws of nature. But we are not forced upon any such mode of conception, or upon any decision between such suppositions: since, for the purpose of our argument, the consequence of either view is the same. There is an adaptation somewhere or other, on either supposition. There is account taken of one part of the system in framing the other: and the mind which took such account can be no other than that of the Intelligent Author of the universe. When indeed we come to see the vast number, the variety, the extent, the interweaving, the reconciling of such adaptations, we shall readily allow, that all things are so moulded upon and locked into each other, connected by such subtilty and profundity of design, that we may well abandon the idle attempt to trace the *order* of thought in the mind of the Supreme Ordainer.

CHAPTER I.

THE LENGTH OF THE YEAR.

A YEAR is the most important and obvious of the periods which occur in the organic, and especially in the vegetable world. In this interval of time the cycle of most of the external influences which operate upon plants is completed. There is also in plants a cycle of internal functions, corresponding to this succession of external causes. The length of either of these periods might have been different from what it is, according to any grounds of necessity which we can perceive. But a certain length is selected in both instances, and in both instances the same. The length of the year is so determined as to be adapted to the constitution of most vegetables; or the construction of vegetables is so adjusted as to be suited to the length which the year really has, and unsuited to a duration longer or shorter by any considerable portion. The vegetable clock-work is so set as to go for a year.

The length of the year or interval of recurrence of the seasons is determined by the time which the earth employs in performing its revolution round the sun: and we can very easily conceive the solar system so adjusted that the year should be longer or shorter than it actually is. We can imagine the earth to revolve round the sun at a distance greater or less than that which it at present has, all the forces of the system remaining unaltered. If the earth were re-

moved towards the centre by about one-eighth of its distance, the year would be diminished by about a month; and in the same manner it would be increased by a month on increasing the distance by one-eighth. We can suppose the earth at a distance of 84 or 108 millions of miles, just as easily as at its present distance of 96 millions: we can suppose the earth with its present stock of animals and vegetables placed where Mars or where Venus is, and revolving in an orbit like one of theirs: on the former supposition our year would become twenty-three, on the latter seven of our present months. Or we can conceive the present distances of the parts of the system to continue what they are, and the size, or the density of the central mass, the sun, to be increased or diminished in any proportion; and in this way the time of the earth's revolution might have been increased or diminished in any degree; a greater velocity, and consequently a diminished period, being requisite, in order to balance an augmented central attraction. In any of these ways the length of the earth's natural year might have been different from what it now is: in the last way without any necessary alteration, so far as we can see, of temperature.

Now, if any change of this kind were to take place, the working of the botanical world would be thrown into utter disorder, the functions of plants would be entirely deranged, and the whole vegetable kingdom involved in instant decay and rapid extinction.

That this would be the case, may be collected from innumerable indications. Most of our fruit trees, for example, require the year to be of its present length. If the summer and the autumn were much shorter, the fruit could not ripen; if these seasons were much longer, the tree would put forth a fresh suit of blossoms, to be cut down by the winter. Or if the year were twice its present length, a second crop of fruit would probably not be matured, for want, among other things, of an intermediate season of rest and consolidation, such as the winter is. Our forest trees in like manner appear to need all the seasons of our present year for their perfection; the spring, summer, and autumn, for the developement of their leaves and consequent formation of their *proper juice*, and of wood from this; and the winter for the hardening and solidifying the substance thus formed.

Most plants, indeed, have some peculiar function adapted to each period of the year, that is of the now existing year. The sap ascends with extraordinary copiousness at two seasons, in the spring and in the autumn, especially the former. The opening of the leaves and the opening of the flowers of the same plants are so constant to their times, (their *appointed* times, as we are naturally led to call them,) that such occurrences might be taken as indications of the times of the year. It has been proposed in this way to select a series of botanical facts which should form a calendar; and this has been termed a *calendar of Flora*. Thus, if we consider the time of

putting forth leaves,* the honeysuckle protrudes them in the month of January; the gooseberry, currant, and elder in the end of February, or beginning of March; the willow, elm, and lime-tree in April; the oak and ash, which are always the latest among trees, in the beginning or towards the middle of May. In the same manner the flowering has its regular time: the mezereon and snow-drop push forth their flowers in February; the primrose in the month of March; the cowslip in April; the great mass of plants in May and June; many in July, August, and September; some not till the month of October, as the meadow saffron; and some not till the approach and arrival of winter, as the laurustinus and arbutus.

The fact which we have here to notice, is the recurrence of these stages in the developement of plants, at intervals precisely or very nearly of twelve months. Undoubtedly, this result is in part occasioned by the action of external stimulants upon the plant, especially heat, and by the recurrence of the intensity of such agents. Accordingly, there are slight differences in the times of such occurrences, according to the backwardness or forwardness of the season, and according as the climate is genial or otherwise. Gardeners use artifices which will, to a certain extent, accelerate or retard the time of developement of a plant. But there are various circumstances which show that this recurrence of the same events and equal intervals is not entirely owing to external causes, and that it depends also upon something in the internal structure of vegetables. Alpine plants do not wait for the stimulus of the sun's heat, but exert such a struggle to blossom, that their flowers are seen among the yet unmelted snow. And this is still more remarkable in the naturalization of plants from one hemisphere to the other. When we transplant our fruit trees to the temperate regions south of the equator, they continue for some years to flourish at the period which corresponds to our spring. The reverse of this obtains, with certain trees of the southern hemisphere. Plants from the Cape of Good Hope, and from Australia, countries whose summer is simultaneous with our winter, exhibit their flowers in the coldest part of the year, as the heaths.

This view of the subject agrees with that maintained by the best botanical writers. Thus Decandolle observes that after making allowance for all meteorological causes, which determine the epoch of flowering, we must reckon as another cause the peculiar nature of each species. The flowering once determined, appears to be subject to a law of *periodicity* and habit.†

It appears then that the functions of plants have by their nature a periodical character; and the length of the period thus belonging to vegetables is a result of their organization. Warmth and light, soil and moisture, may in some degree modify, and hasten or retard the

* London, Encyclopædia of Gardening, 848.

† Dec. Phys. vol. ii. 478.

stages of this period; but when the constraint is removed the natural period is again resumed. Such stimulants as we have mentioned are not the *causes* of this periodicity. They do not produce the varied functions of the plant, and could not occasion their performance at regular intervals, except the plant possessed a suitable construction. They could not alter the length of the cycle of vegetable functions, except within certain very narrow limits. The processes of the rising of the sap, of the formation of proper juices, of the unfolding of leaves, the opening of flowers, the fecundation of the fruit, the ripening of the seed, its proper deposition in order for the reproduction of a new plant;—all these operations require a certain portion of time, and could not be compressed into a space less than a year, or at least could not be abbreviated in any very great degree. And on the other hand, if the winter were greatly longer than it now is, many seeds would not germinate at the return of spring. Seeds which have been kept too long require stimulants to make them fertile.

If therefore the duration of the seasons were much to change, the processes of vegetable life would be interrupted, deranged, distempered. What, for instance, would become of our calendar of Flora, if the year were lengthened or shortened by six months? Some of the dates would never arrive in the one case, and the vegetable processes which mark them would be superseded; some seasons would be without dates in the other case, and these periods would be employed in a way harmful to the plants, and no doubt speedily destructive. We should have not only *a year of confusion*, but, if it were repeated and continued, a year of death.

But in the existing state of things, the duration of the earth's revolution round the sun, and the duration of the revolution of the vegetable functions of most plants are equal. These two periods are *adjusted* to each other. The stimulants which the elements apply come at such intervals and continue for such times, that the plant is supported in health and vigour, and enabled to reproduce its kind. Just such a portion of time is measured out for the vegetable powers to execute their task, as enables them to do so in the best manner.

Now such an adjustment must surely be accepted as a proof of design, exercised in the formation of the world. Why should the solar year be so long and no longer? or, this being of such a length, why should the vegetable cycle be exactly of the same length? Can this be chance? And this occurs, it is to be observed, not in one, or in a few species of plants, but in thousands. Take a small portion only of known species, as the most obviously endowed with this adjustment, and say ten thousand. How should all these organized bodies be constructed for the same period of a year. How should all these machines be wound up so as to go for the same time? Even allowing that they could bear a year of a month longer or shorter, how do they all come within such limits? No chance could produce such a result. And if not by chance, how otherwise could such a

coincidence occur, than by an intentional adjustment of these two things to one another? by a selection of such an organization in plants, as would fit them to the earth on which they were to grow; by an adaptation of construction to conditions; of the scale of construction to the scale of conditions.

It cannot be accepted as an explanation of this fact in the economy of plants, that it is necessary to their existence; that no plants could possibly have subsisted, and come down to us, except those which were thus suited to their place on the earth. This is true; but this does not at all remove the necessity of recurring to design as the origin of the construction by which the existence and continuance of plants is made possible. A watch could not go, except there were the most exact adjustment in the forms and positions of its wheels; yet no one would accept it as an explanation of the origin of such forms and positions, that the watch would not go if these were other than they are. If the objector were to suppose that plants were originally fitted to years of various lengths, and that such only have survived to the present time, as had a cycle of a length equal to our present year, or one which could be accommodated to it; we should reply, that the assumption is too gratuitous and extravagant to require much consideration; but that, moreover, it does not remove the difficulty. How came the functions of plants to be *periodical* at all? Here is, in the first instance, an agreement in the form of the laws that prevail in the organic and in the inorganic world, which appears to us a clear evidence of design in their Author. And the same kind of reply might be made to any similar objection to our argument. Any supposition that the universe has gradually approximated to that state of harmony among the operations of its different parts, of which we have one instance in the coincidence now under consideration, would make it necessary for the objector to assume a previous state of things preparatory to this perfect correspondence. And in this preparatory condition we should still be able to trace the rudiments of that harmony, for which it was proposed to account: so that even the most unbounded licence of hypothesis would not enable the opponent to obliterate the traces of an intentional adaptation of one part of nature to another.

Nor would it at all affect the argument, if these periodical occurrences could be traced to some proximate cause: if for instance it could be shown, that the budding or flowering of plants is brought about at particular intervals, by the nutriment accumulated in their vessels during the preceding months. For the question would still remain, how their functions were so adjusted, that the accumulation of the nutriment necessary for budding and flowering, together with the operation itself, comes to occupy exactly a year, instead of a month only, or ten years. There must be in their structure some reference to time: how did such a reference occur? how was it determined to the particular time of the earth's revolution round

the sun? This could be no otherwise, as we conceive, than by design and appointment.

We are left therefore with this manifest adjustment before us, of two parts of the universe, at first sight so remote; the dimensions of the solar system and the powers of vegetable life. These two things are so related, that one has been made to fit the other. The relation is as clear as that of a watch to a sundial. If a person were to compare the watch with the dial, hour after hour, and day after day, it would be impossible for him not to believe that the watch had been *contrived* to accommodate itself to the solar day. We have at least ten thousand kinds of vegetable watches of the most various forms, which are all accommodated to the solar year; and the evidence of contrivance seems to be no more capable of being eluded in this case than in the other.

The same kind of argument might be applied to the animal creation. The pairing, nesting, hatching, fledging, and flight of birds, for instance, occupy each its peculiar time of the year; and, together with a proper period of rest, fill up the twelve months. The transformations of most insects have a similar reference to the seasons, their progress and duration. "In every species" (except man), says a writer* on animals, "there is a particular period of the year in which the reproductive system exercises its energies. And the season of love and the period of gestation are so arranged that the young ones are produced at the time wherein the conditions of temperature are most suited to the commencement of life." It is not our business here to consider the details of such provisions, beautiful and striking as they are. But the prevalence of the great law of periodicity in the vital functions of organized beings will be allowed to have a claim to be considered in its reference to astronomy, when it is seen that their periodical constitution derives its use from the periodical nature of the motions of the planets round the sun; and that the duration of such cycles in the existence of plants and animals has a reference to the arbitrary elements of the solar system: a reference which, we maintain, is inexplicable and unintelligible, except by admitting into our conceptions an Intelligent Author, alike of the organic and inorganic universe.

* Fleming, Zool. i. 400.

CHAPTER II.

THE LENGTH OF THE DAY.

We shall now consider another astronomical element, the time of the revolution of the earth on its axis; and we shall find here also that the structure of organized bodies is suited to this element;—that the cosmical and physiological arrangements are adapted to each other.

We can very easily conceive the earth to revolve on her axis faster or slower than she does, and thus the days to be longer or shorter than they are, without supposing any other change to take place. There is no apparent reason why this globe should turn on its axis just three hundred and sixty-six times while it describes its orbit round the sun. The revolutions of the other planets, so far as we know them, do not appear to follow any rule by which they are connected with the distance from the sun. Mercury, Venus, and Mars have days nearly the length of ours. Jupiter and Saturn revolve in about ten hours each. For anything we can discover, the earth might have revolved in this or any other smaller period; or we might have had, without mechanical inconvenience, much longer days than we have.

But the terrestrial day, and consequently the length of the cycle of light and darkness, being what it is, we find various parts of the constitution both of animals and vegetables, which have a periodical character in their functions, corresponding to the diurnal succession of external conditions; and we find that the length of the period, as it exists in their constitution, coincides with the length of the natural day.

The alternation of processes which takes place in plants by day and by night is less obvious, and less obviously essential to their well-being, than the annual series of changes. But there are abundance of facts which serve to show that such an alternation is part of the vegetable economy.

In the same manner in which Linnæus proposed a Calendar of Flora, he also proposed a *Dial of Flora*, or Flower-Clock; and this was to consist, as will readily be supposed, of plants, which mark certain hours of the day, by opening and shutting their flowers. Thus the day-lily (*hemerocallis fulva*) opens at five in the morning: the *leontodon taraxacum*, or common dandelion, at five or six; the *hieracium latifolium* (hawk-weed,) at seven; the *hieracium pilosella*, at eight; the *calendula arvensis*, or marigold, at nine; the *mesembryanthemum neapolitanum*, at ten or eleven: and the closing of these and other flowers in the latter part of the day offers a similar system of hour marks.

Some of these plants are thus expanded in consequence of the

stimulating action of the light and heat of the day, as appears by their changing their time, when these influences are changed; but others appear to be constant to the same hours, and independent of the impulse of such external circumstances. Other flowers by their opening and shutting prognosticate the weather. Plants of the latter kind are called by Linnæus, *meteoric* flowers, as being regulated by atmospheric causes: those which change their hour of opening and shutting with the length of the day, he terms *tropical;* and the hours which they measure are, he observes, like Turkish hours, of varying length at different seasons. But there are other plants which he terms *equinoctial;* their vegetable days, like the days of the equator, being always of equal length; and these open, and generally close, at a fixed and positive hour of the day. Such plants clearly prove that the periodical character, and the period of the motions above described, do not depend altogether on external circumstances.

Some curious experiments on this subject were made by Decandolle. He kept certain plants in two cellars, one warmed by a stove and dark, the other lighted by lamps. On some of the plants the artificial light appeared to have no influence, (*convolvulus arvensis, convolvulus cneorum, silene fruticosa*) and they still followed the clock hours in their opening and closing. The night-blowing plants appeared somewhat disturbed, both by perpetual light and perpetual darkness. In either condition they accelerated their *going* so much, that in three days they had gained half a day, and thus exchanged night for day as their time of opening. Other flowers *went slower* in the artificial light (*convolvulus purpureus*). In like manner those plants which fold and unfold their leaves were variously affected by this mode of treatment. The *oxalis stricta* and *oxalis incarnata* kept their habits, without regarding either artificial light or heat. The *mimosa leucocephala* folded and unfolded at the usual times, whether in light or in darkness, but the folding up was not so complete as in the open air. The *mimosa pudica* (sensitive plant), kept in darkness during the day time, and illuminated during the night, had in three days accommodated herself to the artificial state, opening in the evening, and closing in the morning; restored to the open air, she recovered her usual habits.

Tropical plans in general, as remarked by our gardeners, suffer from the length of our summer daylight; and it has been found necessary to shade them during a certain part of the day.

It is clear from these facts, that there is a diurnal period belonging to the constitution of vegetables; though the succession of functions depends in part on the external stimulants, as light and heat, their periodical character is a result of the structure of the plant; and this structure is such, that the length of the period, under the common influences to which plants are exposed, coincides with the astronomical day. The power of accommodation which vegetables

possess in this respect, is far from being such as either to leave the existence of this periodical constitution doubtful, or to entitle us to suppose that the day might be considerably lengthened or shortened without injury to the vegetable kingdom.

Here then we have an adaptation between the structure of plants, and the periodical order of light and darkness which arises from the earth's rotation; and the arbitrary quantity, the length of the cycle of the physiological and of the astronomical fact, is the same. Can this have occurred any otherwise than by an intentional adjustment?

Any supposition that the astronomical cycle has occasioned the physiological one, that the structure of plants has been brought to be what it is by the action of external causes, or that such plants as could not accommodate themselves to the existing day have perished, would be not only an arbitrary and baseless assumption, but moreover useless for the purposes of explanation which it professes, as we have noticed of a similar supposition with respect to the annual cycle. How came plants to have periodicity at all in those functions which have a relation to light and darkness? This part of their constitution was suited to organized things which were to flourish on the earth, and it is accordingly bestowed on them; it was necessary for this end that the period should be of a certain length; it is of that length and no other. Surely this looks like intentional provision.

Animals also have a period in their functions and habits; as in the habits of waking, sleeping, eating, &c. and their well-being appears to depend on the coincidence of this period with the length of the natural day. We see that in the day, as it now is, all animals find seasons for taking food and repose, which agree perfectly with their health and comfort. Some animals feed during the day, as nearly all the ruminating animals and land birds; others feed only in the twilight, as bats and owls, and are called *crepuscular;* while many beasts of prey, aquatic birds, and others, take their food during the night. Those animals which are nocturnal feeders are diurnal sleepers, while those which are crepuscular, sleep partly in the night and partly in the day; but in all, the complete period of these functions is twenty-four hours. Man, in like manner, in all nations and ages, takes his principal rest once in twenty-four hours; and the regularity of this practice seems most suitable to his health, though the duration of the time allotted to repose is extremely different in different cases. So far as we can judge, this period is of a length beneficial to the human frame, independently of the effect of external agents. In the voyages recently made into high northern latitudes, where the sun did not rise for three months, the crews of the ships were made to adhere, with the utmost punctuality, to the habit of retiring to rest at nine, and rising a quarter before six; and they enjoyed, under circumstances apparently the most trying, a

state of salubrity quite remarkable. This shows, that according to the common constitution of such men, the cycle of twenty-four hours is very commodious, though not imposed on them by external circumstances.

The hours of food and repose are capable of such wide modifications in animals, and above all in man, by the influence of external stimulants and internal emotions, that it is not easy to distinguish what portion of the tendency to such alternations depends on original constitution. Yet no one can doubt that the inclination to food and sleep is periodical, or can maintain, with any plausibility, that the period may be lengthened or shortened without limit. We may be tolerably certain that a constantly recurring period of forty-eight hours would be too long for one day of employment and one period of sleep, with our present faculties; and all, whose bodies and minds are tolerably active, will probably agree that, independently of habit, a perpetual alternation of eight hours up and four in bed would employ the human powers less advantageously and agreeably than an alternation of sixteen and eight. A creature which could employ the full energies of his body and mind uninterruptedly for nine months, and then take a single sleep of three months, would not be a man.

When, therefore, we have subtracted from the daily cycle of the employments of men and animals, that which is to be set down to the account of habits acquired, and that which is occasioned by extraneous causes, there still remains a periodical character; and a period of a certain length, which coincides with, or at any rate easily accommodates itself to, the duration of the earth's revolution. The physiological analysis of this part of our constitution is not necessary for our purpose. The succession of exertion and repose in the muscular system, of excited and dormant sensibility in the nervous, appear to be fundamentally connected with the muscular and nervous powers, whatever the nature of these may be. The necessity of these alternations is one of the measures of the intensity of those vital energies; and it would seem that we cannot, without assuming the human powers to be altered, suppose the intervals of tranquillity which they require to be much changed. This view agrees with the opinion of some of the most eminent physiologists. Thus Cabanis* notices the periodical and isochronous character of the desire of sleep, as well as of other appetites. He states also that sleep is more easy and more salutary, in proportion as we go to rest and rise every day at the same hours: and observes that this periodicity seems to have a reference to the motions of the solar system.

Now how should such a reference be at first established in the constitution of man, animals, and plants, and transmitted from one generation of them to another? If we suppose a wise and benevo-

* Rapports du Physique et du Moral de l'Homme, II. 371.

lent Creator, by whom all the parts of nature were fitted to their uses and to each other, this is what we might expect and can understand. On any other supposition such a fact appears altogether incredible and inconceivable.

CHAPTER III.

THE MASS OF THE EARTH.

We shall now consider the adaptation which may, as we conceive, be traced in the amount of some of the quantities which determine the course of events in the organic world; and especially in the amount of the *forces* which are in action. The life of vegetables and animals implies a constant motion of their fluid parts, and this motion must be produced by forces which urge or draw the particles of the fluids. The positions of the parts of vegetables are also the result of the flexibility and elasticity of their substance; the voluntary motions of animals are produced by the tension of the muscles. But in all those cases, the effect really produced depends upon the force of gravity also; and in order that the motions and positions may be such as answer their purpose, the forces which produce them must have a due proportion to the force of gravity. In human works, if, for instance, we have a fluid to raise, or a weight to move, some calculation is requisite, in order to determine the power which we must use, relatively to the work which is to be done: we have a mechanical problem to solve, in order that we may adjust the one to the other. And the same adjustment, the same result of a comparison of quantities, manifests itself in the relation which the forces of the organic world bear to the force of gravity.

The force of gravity might, so far as we can judge, have been different from what it now is. It depends upon the mass of the earth; and this mass is one of the elements of the solar system, which is not determined by any cosmical necessity of which we are aware. The masses of the several planets are very different, and do not appear to follow any determinate rule, except that upon the whole those nearer to the sun appear to be smaller, and those nearer the outskirts of the system to be larger. We cannot see anything which would have prevented either the size or the density of the earth from being different, to a very great extent, from what they are.

Now, it will be very obvious that if the intensity of gravity were to be much increased, or much diminished, if every object were to

become twice as heavy or only half as heavy as it now is, all the forces, both of involuntary and voluntary motion which produce the present orderly and suitable results by being properly proportioned to the resistance which they experience, would be thrown off their balance; they would produce motions too quick or too slow, wrong positions, jerks and stops, instead of steady, well-conducted movements. The universe would be like a machine ill regulated; everything would go wrong; repeated collisions and a rapid disorganization must be the consequence. We will, however, attempt to illustrate one or two of the cases in which this would take place, by pointing out forces which act in the organic world, and which are adjusted to the force of gravity.

1. The first instance we shall take, is the force manifested by the ascent of the sap in vegetables. It appears, by a multitude of indisputable experiments, (among the rest, those of Hales, Mirbel, and Dutrochet,) that all plants imbibe moisture by their roots, and *pump it up*, by some internal force, into every part of their frame, distributing it into every leaf. It will easily be conceived that this operation must require a very considerable mechanical force; for the fluid must be sustained as if it were a single column reaching to the top of the tree. The division into minute parts and distribution through small vessels does not at all diminish the total force requisite to raise it. If, for instance, the tree be thirty-three feet high, the pressure must be fifteen pounds upon every square inch in the section of the vessels of the bottom, in order merely to support the sap. And it is not only supported, but propelled upwards with great force, so as to supply the constant evaporation of the leaves. The pumping power of the tree must, therefore, be very considerable.

That this power is great, has been confirmed by various curious experiments, especially by those of Hales. He measured the force with which the stems and branches of trees draw the fluid from below, and push it upwards. He found, for instance, that a vine in the *bleeding* season could push up its sap in a glass tube to the height of twenty-one feet above the stump of an amputated branch.

The force which produces this effect is part of the economy of the vegetable world; and it is clear that the due operation of the force depends upon its being rightly proportioned to the force of gravity. The weight of the fluid must be counterbalanced, and an excess of force must exist to produce the motion upwards. In the common course of vegetable life, the rate of ascent of the sap is regulated, on the one hand, by the upward pressure of the vegetable power, and on the other, by the amount of the gravity of the fluid, along with the other resistances, which are to be overcome. If, therefore, we suppose gravity to increase, the rapidity of this vegetable circulation will diminish, and the rate at which this function proceeds, will not correspond either to the course of the seasons, or the other physiological processes with which this has to co-

operate. We might easily conceive such an increase of gravity as would stop the vital movements of the plant in a very short time. In like manner, a diminution of the gravity of the vegetable juices would accelerate the rising of the sap, and would, probably, hurry and overload the leaves and other organs, so as to interfere with their due operation. Some injurious change, at least, would take place.

Here, then, we have the forces of the minutest parts of vegetables adjusted to the magnitude of the whole mass of the earth on which they exist. There is no apparent connexion between the quantity of matter of the earth, and the force of imbibition of the roots of a vine, or the force of propulsion of the vessels of its branches. Yet, these things have such a proportion as the well-being of the vine requires. How is this to be accounted for, but by supposing that the circumstances under which the vine was to grow, were attended to in devising its structure?

We have not here pretended to decide whether this force of propulsion of vegetables is mechanical or not, because the argument is the same for our purpose on either supposition. Some very curious experiments have recently been made, (by M. Dutrochet) which are supposed to show that the force is mechanical; that when two different fluids are separated by a thin membrane, a force which M. Dutrochet calls *endosmose* urges one fluid through the membrane: and that the roots of plants are provided with small vesicles which act the part of such a membrane. M. Poisson has further attempted to show that this force of *endosmose* may be considered as a particular modification of capillary action. If these views be true, we have here two mechanical forces, capillary action and gravity, which are adjusted to each other in the manner precisely suited to the welfare of vegetables.

2. As another instance of adaptation between the force of gravity and forces which exist in the vegetable world, we may take the positions of flowers. Some flowers grow with the hollow of their cup upwards: others "hang the pensive head" and turn the opening downwards. Now of these "nodding flowers" as Linnæus calls them, he observes that they are such as have their pistil longer than the stamens; and, in consequence of this position, the dust from the anthers which are at the ends of the stamens can fall upon the stigma or extremity of the pistil; which process is requisite for making the flower fertile. He gives as instances the flowers *campanula, leucoium, galanthus, fritillaria.* Other botanists have remarked that the position changes at different periods of the flower's progress. The pistil of the Euphorbia (which is a little globe or germen on a slender stalk) grows upright at first, and is taller than the stamens: at the period suited to its fecundation, the stalk bends under the weight of the ball at its extremity, so as to depress the germen be-

low the stamens: after this it again becomes erect, the globe being now a fruit filled with fertile seeds.

The positions in all these cases depend upon the length and flexibility of the stalk which supports the flower, or in the case of the Euphorbia, the germen. It is clear that a very slight alteration in the force of gravity, or in the stiffness of the stalk, would entirely alter the position of the flower cup, and thus make the continuation of the species impossible. We have therefore here a little mechanical contrivance, which would have been frustrated if the proper intensity of gravity had not been assumed in the reckoning. An earth greater or smaller, denser or rarer than the one on which we live, would require a change in the structure and strength of the footstalks of all the little flowers that hang their heads under our hedges. There is something curious in thus considering the whole mass of the earth from pole to pole, and from circumference to centre, as employed in keeping a snowdrop in the position most suited to the promotion of its vegetable health.

It would be easy to mention many other parts of the economy of vegetable life, which depend for their use on their adaptation to the force of gravity. Such are the forces and conditions which determine the positions of leaves and of branches. Such again those parts of the vegetable constitution which have reference to the pressure of the atmosphere; for differences in this pressure appear to exercise a powerful influence on the functions of plants, and to require differences of structure. But we pass over these considerations. The slightest attention to the relations of natural objects will show that the subject is inexhaustible; and all that we can or need do is to give a few examples, such as may show the nature of the impression which the examination of the universe produces.

3. Another instance of the adjustment of organic structure to the force of gravity may be pointed out in the muscular powers of animals. If the force of gravity were increased in any considerable proportion at the surface of the earth, it is manifest that all the swiftness, and strength, and grace of animal motions must disappear. If, for instance, the earth were as large as Jupiter, gravity would be eleven times what it is, the lightness of the fawn, the speed of the hare, the spring of the tiger, could no longer exist with the existing muscular powers of those animals; for man to lift himself upright, or to crawl from place to place, would be a labour slower and more painful than the motions of the sloth. The density and pressure of the air too would be increased to an intolerable extent, and the operation of respiration, and others, which depend upon these mechanical properties, would be rendered laborious, ineffectual, and probably impossible.

If, on the other hand, the force of gravity were much lessened, inconveniences of an opposite kind would occur. The air would be too thin to breathe; the weight of our bodies, and of all the sub-

stances surrounding us, would become too slight to resist the perpetually occurring causes of derangement and unsteadiness: we should feel a want of ballast in our movements.

It has sometimes been maintained by fanciful theorists that the earth is merely a shell, and that the central parts are hollow. All the reasons we can collect appear to be in favour of its being a solid mass, considerably denser than any known rock. If this be so, and if we suppose the interior to be at any time scooped out, so as to leave only such a shell, as the above-mentioned speculators have asserted, we should not be left in ignorance of the change, though the appearance of the surface might remain the same. We should discover the want of the usual force of gravity, by the instability of all about us. Things would not lie where we placed them, but would slide away with the slightest push. We should have a difficulty in standing or walking, something like what we have on ship-board when the deck is inclined; and we should stagger helplessly through an atmosphere thinner than that which oppresses the respiration of the traveller on the tops of the highest mountains.

We see therefore that those dark and unknown central portions of the earth, which are placed far beyond the reach of the miner and the geologist, and of which man will probably never know anything directly, are not to be considered as quite disconnected with us, as deposites of useless lumber without effect or purpose. We feel their influence on every step we take and on every breath we draw; and the powers we possess, and the comforts we enjoy would be unprofitable to us, if they had not been prepared with a reference to those as well as to the near and visible portions of the earth's mass.

The arbitrary quantity, therefore, of which we have been treating, the intensity of the force of gravity, appears to have been taken account of, in establishing the laws of those forces by which the processes of vegetable and animal life are carried on. And this leads us inevitably, we conceive, to the belief of a supreme contriving mind, by which these laws were thus devised and thus established.

CHAPTER IV.

THE MAGNITUDE OF THE OCEAN.

There are several arbitrary quantities which contribute to determine the state of things at the earth's surface besides those al-

ready mentioned. Some of these we shall briefly refer to, without pursuing the subject into detail. We wish not only to show that the properties and processes of vegetable and animal life must be adjusted to each of these quantities in particular, but also to point out how numerous and complicated the conditions of the existence of organized beings are; and we shall thus be led to think less inadequately of the intelligence which has embraced at once, and combined without confusion, all these conditions. We appear thus to be conducted to the conviction not only of design and intention, but of supreme knowledge and wisdom.

One of the quantities which enters into the constitution of the terrestrial system of things is the bulk of the waters of the ocean. The mean depth of the sea, according to the calculations of Laplace, is four or five miles. On this supposition, the addition to the sea of one-fourth of the existing waters would drown the whole of the globe, except a few chains of mountains. Whether this be exact or not, we can easily conceive the quantity of water which lies in the cavities of our globe to be greater or less than it at present is. With every such addition or subtraction the form and magnitude of the dry land would vary, and if this change were considerable, many of the present relations of things would be altered. It may be sufficient to mention one effect of such a change. The sources which water the earth, both clouds, rains, and rivers, are mainly fed by the aqueous vapour raised from the sea; and therefore if the sea were much diminished, and the land increased, the mean quantity of moisture distributed upon the land must be diminished, and the character of climates, as to wet and dry, must be materially affected. Similar, but opposite changes would result from the increase of the surface of the ocean.

It appears then that the magnitude of the ocean is one of the conditions to which the structure of all organized beings which are dependent upon climate must be adapted.

CHAPTER V.

THE MAGNITUDE OF THE ATMOSPHERE.

The total quantity of air of which our atmosphere is composed is another of the arbitrary magnitudes of our terrestrial system; and we may apply to this subject considerations similar to those of the last section. We can see no reason why the atmosphere might not have been larger in comparison to the globe which it surrounds; those of Mars and Jupiter appear to be so. But if the quantity of

air were increased, the structure of organized beings would in many ways cease to be adapted to their place. The atmospheric pressure, for instance, would be increased, which, as we have already noticed, would require an alteration in the structure of vegetables.

Another way in which an increase of the mass of the atmosphere would produce inconvenience would be in the force of winds. If the current of air in a strong gale were doubled or tripled, as might be the case if the atmosphere were augmented, the destructive effects would be more than doubled or tripled. With such a change, nothing could stand against a storm. In general, houses and trees resist the violence of the wind; and except in extreme cases, as for instance in occasional hurricanes in the West Indies, a few large trees in a forest are unusual trophies of the power of the tempest. The breezes which we commonly have are harmless messengers to bring about the salutary changes of the atmosphere, even the motion which they communicate to vegetables tends to promote their growth, and is so advantageous, that it has been proposed to imitate it by artificial breezes in the hothouse. But with a stream of wind blowing against them, like three, or five, or ten, gales compressed into the space of one, none of the existing trees could stand; and except they could either bend like rushes in a stream, or extend their roots far wider than their branches, they must be torn up in whole groves. We have thus a manifest adaptation of the present usual strength of the materials and of the workmanship of the world to the stress of wind and weather which they have to sustain.

CHAPTER VI.

THE CONSTANCY AND VARIETY OF CLIMATES.

It is possible to conceive arrangements of our system, according to which all parts of the earth might have the same, or nearly the same, climate. If, for example, we suppose the earth to be a flat disk, or flat ring, like the ring of Saturn, revolving in its own plane as that does, each part of both the flat surfaces would have the same exposure to the sun, and the same temperature, so far as the sun's effect is concerned. There is no obvious reason why a planet of such a form might not be occupied by animals and vegetables, as well as our present earth; and on this supposition the climate would be every where the same, and the whole surface might be covered with life, without the necessity of there being any difference in the kind of inhabitants belonging to different parts.

Again, it is possible to conceive arrangements according to which

no part of our planet should have any steady climate. This may probably be the case with a comet. If we suppose such a body, revolving round the sun in a very oblong ellipse, to be of small size and of a very high temperature, and therefore to cool rapidly; and if we suppose it also to be surrounded by a large atmosphere, composed of various gases; there would, on the surface of such a body, be no average climate or seasons for each place. The years, if we give this name to the intervals of time occupied by its successive revolutions, would be entirely unlike one another. The greatest heat of one year might be cool compared with the greatest cold of a preceding one. The greatest heats and colds might succeed each other at intervals perpetually unequal. The atmosphere might be perpetually changing its composition by the condensation of some of its constituent gases. In the operations of the elements, all would be incessant and rapid change, without recurrence or compensation. We cannot say that organized beings could not be fitted for such a habitation; but if they were, the adaptation must be made by means of a constitution quite different from that of almost all organized beings known to us.

The state of things upon the earth, in its present condition, is very different from both these suppositions. The climate of the same place, notwithstanding perpetual and apparently irregular change, possesses a remarkable steadiness. And, though in different places the annual succession of appearances in the earth and heavens, is, in some of its main characters, the same, the result of these influences in the average climate is very different.

Now, to this remarkable constitution of the earth as to climate, the constitution of the animal and vegetable world is precisely adapted. The differences of different climates are provided for by the existence of entirely different classes of plants and animals in different countries. The constancy of climate at the same place is a necessary condition of the prosperity of each species there fixed.

We shall illustrate, by a few details, these characteristics in the constitution of inorganic and of organic nature, with the view of fixing the reader's attention upon the correspondence of the two.

1. The succession and alternation, at any given place, of heat and cold, rain and sunshine, wind and calm, and other atmospheric changes, appears at first sight to be extremely irregular, and not subject to any law. It is, however, easy to see, with a little attention, that there is a certain degree of constancy in the average weather and seasons of each place, though the particular facts of which these generalities are made up seem to be out of the reach of fixed laws. And when we apply any numerical measure to these particular occurrences, and take the average of the numbers thus observed, we generally find a remarkably close correspondence in the numbers belonging to the whole, or to analogous portions of successive years. This will be found to apply to the measures given by the thermome-

ter, the barometer, the hygrometer, the raingauge, and similar instruments. Thus it is found that very hot summers, or very cold winters, raise or depress the mean annual temperature very little above or below the general standard.

The heat may be expressed by degrees of the thermometer; the temperature of the day is estimated by this measure taken at a certain period of the day, which is found by experience to correspond with the daily average; and the mean annual temperature will then be the average of all the heights of the thermometer for every day in the year.

The mean annual temperature of London, thus measured, is about 50 degrees 4-10ths. The frost of the year 1788 was so severe that the Thames was passable on the ice; the mean temperature of that year was 50 degrees 6-10ths, being within a small fraction of a degree of the standard. In 1796, when the greatest cold ever observed in London occurred, the mean temperature of the year was 50 degrees 1-10th, which is likewise within a fraction of a degree of the standard. In the severe winter of 1813-14, when the Thames, Tyne, and other large rivers in England were completely frozen over, the mean temperature of the two years was 49 degrees, being little more than a degree below the standard. And in the year 1808, when the summer was so hot that the temperature in London was as high as $93\frac{1}{2}$, degrees, the mean heat of the year was $50\frac{1}{2}$, which is about that of the standard.

The same numerical indications of the constancy of climate at the same place might be collected from the records of other instruments of the kind above-mentioned.

We shall, hereafter, consider some of the very complex agencies by which this steadiness is produced; and shall endeavour to point out intentional adaptations to this object. But we may, in the meantime, observe how this property of the atmospheric changes is made subservient to a further object.

To this constancy of the climates of each place, the structu · of plants is adapted; almost all vegetables require a particular mean temperature of the year, or of some season of the year; a particular degree of moisture, and similar conditions. This will be seen by observing that the range of most plants as to climate is very limited. A vegetable which flourishes where the mean temperature is 55 degrees, would pine and wither when removed to a region where the average is 50 degrees. If, therefore, the average at each place were to vary as much as this, our plants with their present constitutions would suffer, languish, and soon die.

2. It will be readily understood that the same mode of measurement by which we learn the constancy of climate at the same place, serves to show us the variety which belongs to different places. While the variations of the same region vanish when we take the averages even of moderate periods, those of distant countries are fixed and

perpetual; and stand out more clear and distinct, the longer is the interval for which we measure their operation.

In the way of measuring already described, the mean temperature of Petersburg is 39 degrees, of Rome, 60, of Cairo 72. Such observations as these, and others of the same kind, have been made at various places, collected and recorded; and in this way the surface of the earth can be divided by boundary lines into various strips, according to these physical differences. Thus, the zones which take in all the places having the same or nearly the same mean annual temperature, have been called *isothermal* zones. These zones run nearly parallel to the equator, but not exactly, for, in Europe, they bend to the north in going eastward. In the same manner, the lines passing through all places which have an equal temperature for the summer or the winter half of the year, have been called respectively *isotheral* and *isochimal* lines. These do not coincide with the isothermal lines, for a place may have the same temperature as another, though its summer be hotter and its winter colder, as is the case of Pekin compared with London. In the same way we might conceive lines drawn according to the conditions of clouds, rain, wind, and the like circumstances, if we had observations enough to enable us to lay down such lines. The course of vegetation depends upon the combined influence of all such conditions; and the lines which bound the spread of particular vegetable productions do not, in most cases, coincide with any of the separate meteorological boundaries above spoken of. Thus, the northern limit of vineyards runs through France, in a direction very nearly north-east and south-west, while the line of equal temperature is nearly east and west. And the spontaneous growth or advantageous cultivation of other plants, is in like manner bounded by lines of which the course depends upon very complex causes, but of which the position is generally precise and fixed.

CHAPTER VII.

THE VARIETY OF ORGANIZATION CORRESPONDING TO THE VARIETY OF CLIMATE.

The organization of plants and animals is in different tribes formed upon schemes more or less different, but in all cases adjusted in a general way to the course and action of the elements. The dif-

ferences are connected with the different habits and manners of living which belong to different species; and at any one place the various species, both of animals and plants, have a number of relations and mutual dependences arising out of these differences. But besides the differences of this kind, we find in the forms of organic life another set of differences, by which the animal and vegetable kingdom are fitted for that variety in the climates of the earth, which we have been endeavouring to explain.

The existence of such differences is too obvious to require to be dwelt upon. The plants and animals which flourish and thrive in countries remote from each other, offer to the eye of the traveller a series of pictures, which, even to an ignorant and unreflective spectator, is full of a peculiar and fascinating interest in consequence of the novelty and strangeness of the successive scenes.

Those who describe the countries between the tropics, speak with admiration of the luxuriant profusion and rich variety of the vegetable productions of those regions. Vegetable life seems there far more vigorous and active, the circumstances under which it goes on, far more favourable than in our latitudes. Now if we conceive an inhabitant of those regions, knowing, from the circumstances of the earth's form and motion, the difference of climates which must prevail upon it, to guess, from what he saw about him, the condition of other parts of the globe as to vegetable wealth, is it not likely that he would suppose that the extratropical climates must be almost devoid of plants? We know that the ancients, living in the temperate zone, came to the conclusion that both the torrid and the frigid zones must be uninhabitable. In like manner the equatorial reasoner would probably conceive that vegetation must cease, or gradually die away, as he should proceed to places further and further removed from the genial influence of the sun. The mean temperature of his year being about 80 degrees, he would hardly suppose that any plants could subsist through a year, where the mean temperature was only 50, where the temperature of the summer quarter was only 64, and where the mean temperature of a whole quarter of the year was a very few degrees removed from that at which water becomes solid. He would suppose that scarcely any tree, shrub, or flower could exist in such a state of things, and so far as the plants of his own country are concerned he would judge rightly.

But the countries further removed from the equator are not left thus unprovided. Instead of being scantily occupied by such of the tropical plants as could support a stunted and precarious life in ungenial climes, they are abundantly stocked with a multitude of vegetables which appear to be constructed expressly for them, inasmuch as these species can no more flourish at the equator than the equatorial species can in these temperate regions. And such new supplies thus adapted to new conditions, recur perpetually as we advance towards the apparently frozen and untenantable regions in

the neighbourhood of the pole. Every zone has its peculiar vegetables; and as we miss some, we find others make their appearance, as if to replace those which are absent.

If we look at the indigenous plants of Asia and Europe, we find such a succession as we have here spoken of. At the equator we find the natives of the Spice Islands, the clove and nutmeg trees, pepper and mace. Cinnamon bushes clothe the surface of Ceylon; the odoriferous sandal wood, the ebony tree, the teak tree, the banyan, grow in the East Indies. In the same latitudes in Arabia the Happy we find balm, frankincense and myrrh, the coffee tree, and the tamarind. But in these countries, at least in the plains, the trees and shrubs which decorate our more northerly climes are wanting. And as we go northwards, at every step we change the vegetable group, both by addition and subtraction. In the thickets to the west of the Caspian Sea we have the apricot, citron, peach, walnut. In the same latitude in Spain, Sicily, and Italy, we find the dwarf palm, the cypress, the chestnut, the cork tree: the orange and lemon tree perfume the air with their blossoms; the myrtle and pomegranate grow wild among the rocks. We cross the Alps, and we find the vegetation which belongs to northern Europe, of which England is an instance. The oak, the beech, and the elm are natives of Great Britain: the elm tree seen in Scotland, and in the north of England, is the wych elm. As we travel still further to the north the forests again change their character. In the northern provinces of the Russian empire are found forests of the various species of firs: the scotch and spruce fir, and the larch. In the Orkney Islands no tree is found but the hazel, which occurs again on the northern shores of the Baltic. As we proceed into colder regions we still find species which appear to have been made for these situations. The hoary or cold elder makes its appearance north of Stockholm: the sycamore and mountain ash accompany us to the head of the gulf of Bothnia: and as we leave this and traverse the Dophrian range, we pass in succession the boundary lines of the spruce fir, the scotch fir, and those minute shrubs which botanists distinguish as the dwarf birch and dwarf willow. Here, near to or within the arctic circle, we yet find wild flowers of great beauty; the mezereum, the yellow and white water lily, and the European globe flower. And when these fail us, the reindeer moss still makes the country habitable for animals and man.

We have thus a variety in the laws of vegetable organization remarkably adapted to the variety of climates; and by this adaptation the globe is clothed with vegetation and peopled with animals from pole to pole, while without such an adaptation vegetable and animal life must have been confined almost, or entirely, to some narrow zone on the earth's surface. We conceive that we see here the evidence of a wise and benevolent intention, overcoming the varying difficulties, or employing the varying resources of the elements, with

an inexhaustible fertility of contrivance, a constant tendency to diffuse life and well being.

2. One of the great uses to which the vegetable wealth of the earth is applied, is the support of man, whom it supplies with food and clothing; and the adaptation of tribes of indigenous vegetables to every climate has, we cannot but believe, a reference to the intention that the human race should be diffused over the whole globe. But this end is not answered by indigenous vegetables alone; and in the variety of vegetables capable of being *cultivated* with advantage in various countries, we conceive that we find evidence of an additional adaptation of the scheme of organic life to the system of the elements.

The cultivated vegetables, which form the necessaries or luxuries of human life, are each confined within limits, narrow, when compared with the whole surface of the earth; yet almost every part of the earth's surface is capable of being abundantly covered with one kind or other of these. When one class fails, another appears in its place. Thus corn, wine, and oil, have each its boundaries. Wheat extends through the old Continent, from England to Thibet: but it stops soon in going northwards, and is not found to succeed in the west of Scotland. Nor does it thrive better in the torrid zone than in the polar regions: within the tropics, wheat, barley and oats are not cultivated, excepting in situations considerably above the level of the sea: the inhabitants of those countries have other species of grain, or other food. The cultivation of the vine succeeds only in countries where the annual temperature is between 50 and 63 degrees. In both hemispheres, the profitable culture of this plant ceases within 30 degrees of the equator, unless in elevated situations, or in islands, as Teneriffe. The limits of the cultivation of maize and of olives in France are parallel to those which bound the vine and corn in succession to the north. In the north of Italy, west of Milan, we first meet with the cultivation of rice; which extends over all the southern parts of Asia, wherever the land can be at pleasure covered with water. In great part of Africa millet is one of the principal kinds of grain.

Cotton is cultivated to latitude 40 in the new world, but extends to Astrachan in latitude 46 in the old. The sugar cane, the plantain, the mulberry, the betel nut, the indigo tree, the tea tree, repay the labours of the cultivator in India and China; and several of these plants have been transferred, with success, to America and the West Indies. In equinoctial America a great number of inhabitants find abundant nourishment on a narrow space cultivated with plantain, cassava yams, and maize. The bread fruit tree begins to be cultivated in the Manillas, and extends through the Pacific; the sago palm in the Moluccas, the cabbage tree in the Pelew islands.

In this manner the various tribes of men are provided with vegetable food. Some however live on their cattle, and thus make the

produce of the earth only mediately subservient to their wants. Thus the Tatar tribes depend on their flocks and herds for food: the taste for the flesh of the horse seems to belong to the Mongols, Fins, and other descendants of the ancient Scythians: the locust eaters are found now, as formerly, in Africa.

Many of these differences depend upon custom, soil, and other causes with which we do not here meddle; but many are connected with climate: and the variety of the resources which man thus possesses, arises from the variety of constitution belonging to cultivable vegetables, through which one is fitted to one range of climate, and another to another. We conceive that this variety and succession of fitness for cultivation, shows undoubted marks of a most foreseeing and benevolent design in the Creator of man and of the world.

3. By differences in vegetables of the kind we have above described, the sustentation and gratification of man's physical nature is copiously provided for. But there is another circumstance, a result of the difference of the native products of different regions, and therefore a consequence of that difference of climate on which the difference of native products depends,* which appears to be worthy our notice. The difference of the productions of different countries has a bearing not only upon the physical, but upon the social and moral condition of man.

The intercourse of nations in the way of discovery, colonization, commerce; the study of the natural history, manners, institutions of foreign countries; lead to most numerous and important results. Without dwelling upon this subject, it will probably be allowed that such intercourse has a great influence upon the comforts, the prosperity, the arts, the literature, the power, of the nations which thus communicate. Now the variety of the productions of different lands supplies both the stimulus to this intercourse, and the instruments by which it produces its effects. The desire to possess the objects or the knowledge which foreign countries alone can supply, urges the trader, the traveller, the discoverer to compass land and sea; and the progress of the arts and advantages of civilization consists almost entirely in the cultivation, the use, the improvement of that which has been received from other countries.

This is the case to a much greater extent than might at first sight be supposed. Where man is active as a cultivator, he scarcely ever bestows much of his care on those vegetables which the land would produce in a state of nature. He does not select some of the plants of the soil and improve them by careful culture, but, for the most part, he expels the native possessors of the land, and introduces colonies of strangers.

Thus, to take the condition of our own part of the globe as an ex-

* It will be observed that it is not here asserted that the difference of native products depends on the difference of climate *alone*.

ample; scarcely one of the plants which occupy our fields and gardens is indigenous to the country. The walnut and the peach come to us from Persia; the apricot from Armenia: from Asia Minor, and Syria, we have the cherry tree, the fig, the pear, the pomegranate, the olive, the plum, and the mulberry. The vine which is now cultivated is not a native of Europe; it is found wild on the shores of the Caspian, in Armenia and Caramania. The most useful species of plants, the *cereal* vegetables, are certainly strangers, though their birth place seems to be an impenetrable secret. Some have fancied that barley is found wild on the banks of the Semara, in Tartary, rye in Crete, wheat at Baschkiros, in Asia; but this is held by the best botanists to be very doubtful. The potato, which has been so widely diffused over the world in modern times, and has added so much to the resources of life in many countries, has been found equally difficult to trace back to its wild condition.

Thus widely are spread the traces of the connexion of the progress of civilization with national intercourse. In our own country a higher state of the arts of life is marked by a more ready and extensive adoption of foreign productions. Our fields are covered with herbs from Holland, and roots from Germany; with Flemish farming and Swedish turnips; our hills with forests of the firs of Norway. The chestnut and poplar of the south of Europe adorn our lawns, and below them flourish shrubs and flowers from every clime in profusion. In the mean time Arabia improves our horses, China our pigs, North America our poultry, Spain our sheep, and almost every country sends its dog. The products which are ingredients in our luxuries, and which we cannot naturalize at home, we raise in our colonies; the cotton, coffee, sugar of the east are thus transplanted to the farthest west; and man lives in the middle of a rich and varied abundance which depends on the facility with which plants and animals and modes of culture can be transferred into lands far removed from those in which nature had placed them. And this plenty and variety of material comforts is the companion and the mark of advantages and improvements in social life, of progress in art and science, of activity of thought, of energy of purpose, and of ascendency of character.

The differences in the productions of different countries which lead to the habitual intercourse of nations, and through this to the benefits which we have thus briefly noticed, do not all depend upon the differences of temperature and climate alone. But these differences are among the causes, and are some of the most important causes, or conditions, of the variety of products; and thus that arrangement of the earth's form and motion from which the different climates of different places arises, is connected with the social and moral welfare and advancement of man.

We conceive that this connexion, though there must be to our apprehension much that is indefinite and uncertain in tracing its de-

tails, is yet a point where we may perceive the profound and comprehensive relations established by the counsel and foresight of a wise and good Creator of the world and of man, by whom the progress and elevation of the human species was neither uncontemplated nor uncared for.

4. We have traced, in the variety of organized beings, an *adaptation* to the variety of climates, a *provision* for the sustentation of man all over the globe, and an *instrument* for the promotion of civilization and many attendant benefits. We have not considered this *variety* as *itself* a purpose which we can perceive or understand without reference to some ulterior end. Many persons, however, and especially those who are already in the habit of referring the world to its Creator, will probably see something admirable in itself in this vast variety of created things. There is indeed something well fitted to produce and confirm a reverential wonder, in these apparently inexhaustible stores of new forms of being and modes of existence; the fixity of the laws of each class, its distinctness from all others, its relations to many. Structures and habits and characters are exhibited, which are connected and distinguished according to every conceivable degree of subordination and analogy, in their resemblances and in their differences. Every new country we explore presents us with new combinations, where the possible cases seemed to be exhausted; and with new resemblances and differences, constructed as if to elude what conjecture might have hit upon, by proceeding from the old ones. Most of those who have any large portion of nature brought under their notice in this point of view, are led to feel that there is, in such a creation, a harmony, a beauty, and a dignity, of which the impression is irresistible; which would have been wanting in any more uniform and limited system such as we might try to imagine; and which of itself gives to the arrangements by which such a variety on the earth's surface is produced, the character of well devised means to a worthy end.

CHAPTER VIII.

THE CONSTITUENTS OF CLIMATE.

We have spoken of the steady average of the climate at each place, of the difference of this average at different places, and of the adaptation of organized beings to this character in the laws of the elements by which they are affected. But this steadiness in the general effect of the elements, is the result of an ex-

tremely complex and extensive machinery. Climate, in its wider sense, is not one single agent, but is the aggregate result of a great number of different agents, governed by different laws, producing effects of various kinds. The steadiness of this compound agency is not the steadiness of a permanent condition, like that of a body at rest; but it is the steadiness of a state of constant change and movement, succession and alternation, seeming accident and irregularity. It is a perpetual repose, combined with a perpetual motion; an invariable average of most variable quantities. Now, the manner in which such a state of things is produced, deserves, we conceive, a closer consideration. It may be useful to show how the particular laws of the action of each of the elements of climate are so adjusted that they do not disturb this general constancy.

The principal constituents of climate are the following:—the temperature of the earth, of the water, of the air:—the distribution of the aqueous vapour contained in the atmosphere:—the winds and rains by which the equilibrium of the atmosphere is restored when it is in any degree disturbed. The effects of light, of electricity, probably of other causes also, are no doubt important in the economy of the vegetable world, but these agencies have not been reduced by scientific inquirers to such laws as to admit of their being treated with the same exactness and certainty which we can obtain in the case of those first mentioned.

We shall proceed to trace some of the peculiarities in the laws of the different physical agents which are in action at the earth's surface, and the manner in which these peculiarities bear upon the general result.

The Laws of Heat with respect to the Earth.

One of the main causes which determine the temperature of each climate is the effect of the sun's rays on the solid mass of the earth. The laws of this operation have been recently made out with considerable exactness, experimentally by Leslie, theoretically by Fourrier, and by other inquirers. The theoretical inquiries have required the application of very complex and abstruse mathematical investigations; but the general character of the operation may, perhaps, be made easily intelligible.

The earth, like all solid bodies, transmits into its interior the impressions of heat which it receives at the surface; and throws off the superfluous heat from its surface into the surrounding space. These processes are called *conduction* and *radiation*, and have each their ascertained mathematical laws.

By the laws of conduction, the daily impressions of heat which the earth receives, follow each other into the interior of the mass,

like the waves which start from the edge of a canal*; and like them, become more and more faint as they proceed, till they melt into the general level of the internal temperature. The heat thus transmitted is accumulated in the interior of the earth, as in a reservoir, and flows from one part to another of this reservoir. The parts of the earth near the equator are more heated by the sun than other parts, and on this account there is a perpetual internal conduction of heat from the equatorial to other parts of the sphere. And as all parts of the surface throw off heat by radiation, in the polar regions, where the surface receives little in return from the sun, a constant waste is produced. There is thus from the polar parts a perpetual dispersion of heat in the surrounding space, which is supplied by a perpetual internal flow from the equator towards each pole.

Here, then, is a kind of circulation of heat; and the quantity and rapidity of this circulation, determine the quantity of heat in the solid part of the earth, and in each portion of it; and through this, the *mean* temperature belonging to each point on its surface.

If the earth *conducted* heat more rapidly than it does, the inequalities of temperature would be more quickly balanced, and the temperature of the ground (below the reach of annual and diurnal variations) would differ less than it does. If the surface *radiated*, more rapidly than it does, the flow of heat from the polar regions would increase, and the temperature of the interior of the globe would find a lower level; the differences of temperature in different latitudes would increase, but the mean temperature of the globe would diminish.

There is nothing which, so far as we can perceive, determines necessarily, either the conducting or the radiating power of the earth to its present value. The measures of such powers, in different substances, differ very widely. If the earth were a globe of pure iron, it would conduct heat, probably, twenty times as well as it does; if its surface were polished iron, it would only radiate one-sixth as much as it does. Changes in the amount of the conduction and radiation far less than these, would, probably, subvert the whole *thermal* constitution of the earth, and make it uninhabitable by any of its present vegetable, or animal tenants.

One of the results of the laws of heat, as they exist in the globe, is, that, by their action, the thermal state tends to a limiting condition, which, once reached, remains constant and steady, as it now is.

* The resemblance consists in this; that we have a strip of greater temperature accompanied by a strip of smaller temperature, these strips arising fuom the diurnal and nocturnal impressions respectively, and being in motion; as in the waves on a canal, we have a moving strip of greater elevation accompanied by a strip of smaller elevation. We do not here refer to any hypothetical undulations in the fluid matter of heat.

The oscillations or excursions from the mean condition, produced by any temporary cause, are rapidly suppressed; the deviations of seasons from their usual standard produce only a small and transient effect. The impression of an extremely hot day upon the ground melts almost immediately into the average internal heat. The effect of a hot summer, in like manner, is soon lost in its progress through the globe. If this were otherwise, if the inequalities and oscillations of heat went on, through the interior of the earth, retaining the same value, or becoming larger and larger, we might have the extreme heats or colds of one place making their appearance at another place after a long interval; like a conflagration which creeps along the street and bursts out at a point remote from its origin.

It appears, therefore, that both the present differences of climate, and the steadiness of the average at each place, depend upon the form of the present laws of heat, and on the arbitrary magnitudes which determine the rate of conduction and radiation. The laws are such as to secure us from increasing and destructive inequalities of heat; the arbitrary magnitudes are elements to which the organic world is adjusted.

CHAPTER IX.

THE LAWS OF HEAT WITH RESPECT TO WATER.

The manner in which heat is transmitted through fluids is altogether different from the mode in which it passes through solids; and hence the waters of the earth's surface produce peculiar effects upon its condition as to temperature. Moreover, water is susceptible of evaporation in a degree depending upon the increase of heat; and in consequence of this property it has most extensive and important functions to discharge in the economy of nature. We will consider some of the offices of this fluid.

1. Heat is communicated through water, not by being *conducted* from one part of the fluid to another, as in solid bodies, but (at least principally) by being *carried* with the parts of the fluid by means of an intestine motion. Water expands and becomes lighter by heat, and, therefore, if the upper parts be cooled below the subjacent temperature, this upper portion will become heavier than that below, bulk for bulk, and will descend through it, while the lower portion rises to take the upper place. In this manner the colder parts descend, and the warmer parts ascend by contrary currents, and by their interchange and mixture, reduce the whole to a temperature

at least as low as that of the surface. And this equalization of temperature by means of such currents, is an operation of a much more rapid nature than the slow motion of conduction by which heat creeps through a solid body. Hence, alternations of heat and cold, as day and night, summer and winter, produce in water, inequalities of temperature much smaller than those which occur in a solid body. The heat communicated is less, for transparent fluids imbibe heat very slowly; and the cold impressed on the surface is soon diffused through the mass by internal circulation.

Hence it follows that the ocean, which covers so large a portion of the earth, and affects the temperature of the whole surface by its influence, produces the effect of making the alternations of heat and cold much less violent than they would be if it were absent. The different temperatures of its upper and lower parts produce a current which draws the seas, and by means of the seas, the air, towards the mean temperature. And this kind of circulation is produced, not only between the upper and lower parts, but also between distant tracts of the ocean. The great Gulf Stream which rushes out of the gulf of Mexico, and runs across the Atlantic to the western shores of Europe, carries with it a portion of the tropical heat into northern regions: and the returning current which descends along the coast of Africa, tends to cool the parts nearer the equator. Great as the difference of temperature is in different climates, it would be still greater if there were not this equalizing and moderating power exerted constantly over the whole surface. Without this influence, it is probable that the two polar portions of the earth, which are locked in perpetual ice and snow, and almost destitute of life, would be much increased.

We find an illustration of this effect of the ocean on temperature, in the peculiarities of the climates of maritime tracts and islands. The climate of such portions of the earth, corrected in some measure by the temperature of the neighbouring sea, is more equable than that of places in the same latitudes differently situated. London is cooler in summer and warmer in winter than Paris.

2. Water expands by heat and contracts by cold, as has been already said; and in consequence of this property, the coldest portions of the fluid generally occupy the lower parts. The continued progress of cold produces congelation. If, therefore, the law just mentioned had been strictly true, the lower parts of water would have been first frozen; and being once frozen, hardly any heat applied at the surface could have melted them, for the warm fluid could not have descended through the colder parts. This is so far the case, that in a vessel containing ice at the bottom and water at the top, Rumford made the upper fluid boil without thawing the congealed cake below.

Now, a law of water with respect to heat operating in this manner, would have been very inconvenient if it had obtained in our

lakes and seas. They would all have had a bed of ice, increasing with every occasion, till the whole was frozen. We could have had no bodies of water, except such pools on the surfaces of these icy reservoirs as the summer sun could thaw, to be again frozen to the bottom with the first frosty night. The law of the regular contraction of water by cold till it became ice, would, therefore, be destructive of all the utility of our seas and lakes. How is this inconvenience obviated?

It is obviated by a modification of the law which takes place when the temperature approaches this limit. Water contracts by the increase of cold, till we come *near* the freezing temperature; but then, by a further increase of cold, it contracts no more, but expands till the point at which it becomes ice. It contracts in cooling down to 40 degrees of Fahrenheit's thermometer; in cooling further it expands, and when cooled to 32 degrees, it freezes. Hence, the greatest density of the fluid is at 40 degrees, and water of this temperature, or near it, will lie at the bottom with cooler water or with ice floating above it. However much the surface be cooled, water colder than 40 cannot descend to displace water warmer than itself. Hence we can never have ice formed at the bottom of deep water. In approaching the freezing point, the coldest water will rise to the surface, and the congelation will take place there; and the ice so formed will remain at the surface, exposed to the warmth of the sun-beams and the air, and will not survive any long continuance of such action.

Another peculiarity in the laws which regulate the action of cold on water is, that in the very act of freezing a further sudden and considerable expansion takes place. Many persons will have known instances of vessels burst by the freezing of water in them. The consequence of this expansion is, that the specific gravity of ice is less than that of water of any temperature; and it therefore always floats in the unfrozen fluid. If this expansion of crystallization did not exist, ice would float in water which was below 40 degrees, but would sink when the fluid was above that temperature: as the case is, it floats under all circumstances. The icy remnants of the effects of winter, which the river carries down its stream, are visible on its surface till they melt away; and the icebergs which are detached from the shores of the polar seas, drift along, exposed to the sun and air, as well as to the water in which they are immersed.

These laws of the effect of temperature on water are truly remarkable in their adaptation to the beneficial course of things at the earth's surface. Water contracts by cold; it thus equalizes the temperature of various times and places; but if its contraction were continued all the way to the freezing point, it would bind a great part of the earth in fetters of ice. The contraction then is here replaced by expansion, in a manner which but slightly modifies the former effects, while it completely obviates the bad consequences.

The further expansion which takes place at the point of freezing, still further facilitates the rapid removal of the icy chains, in which parts of the earth's surface are at certain seasons bound.

We do not know how far these laws of expansion are connected with and depend on more remote and general properties of this fluid, or of all fluids. But we have no reason to believe that, by whatever means they operate, they are not laws selected from among other laws which might exist, as in fact for other fluids other laws do exist. And we have all the evidence, which the most remarkable furtherance of important purposes can give us, that they *are* selected, and selected with a beneficial design.

3. As water becomes ice by cold, it becomes steam by heat. In common language, steam is the name given to the vapour of *hot* water; but in fact a vapour or steam rises from water at all temperatures, however low, and even from ice. The expansive force of this vapour increases rapidly as the heat increases; so that when we reach the heat of boiling water, it operates in a far more striking manner than when it is colder; but in all cases the surface of water is covered with an atmosphere of aqueous vapour, the pressure or *tension* of which is limited by the temperature of the water. To each degree of pressure in steam there is a *constituent temperature* corresponding. If the surface of water is not pressed by vapour with the force thus corresponding to its temperature, an immediate *evaporation* will supply the deficiency. We can compare the tension of such vapour with that of our common atmosphere; the pressure of the latter is measured by the barometrical column, about thirty inches of mercury; that of watery vapour is equal to one inch of mercury at the constituent temperature of 80 degrees, and to one-fifth of an inch, at the temperature of 32 degrees.

Hence, if that part of the atmosphere which consists of common air were annihilated, there would still remain an atmosphere of aqueous vapour, arising from the waters and moist parts of the earth; and in the existing state of things this vapour rises *in* the atmosphere of dry air. Its distribution and effects are materially influenced by the vehicle in which it is thus carried, as we shall hereafter notice; but at present we have to observe the exceeding *utility* of water in this shape. We remark how suitable and indispensable to the well-being of the creation it is, that the fluid should possess the property of assuming such a form under such circumstances.

The *moisture* which floats in the atmosphere is of most essential use to vegetable life.* "The leaves of living plants appear to act upon this vapour in its elastic form, and to absorb it. Some vegetables increase in weight from this cause when suspended in the atmosphere and unconnected with the soil, as the house-leek and the aloe. In very intense heats, and when the soil is dry, the life of

* Loudon, 1219.

plants seems to be preserved by the absorbent power of their leaves." It follows from what has already been said, that, with an increasing heat of the atmosphere, an increasing quantity of vapour will rise into it, if supplied from any quarter. Hence it appears that aqueous vapour is most abundant in the atmosphere when it is most needed for the purposes of life; and that when other sources of moisture are cut off, this is most copious.

4. *Clouds* are produced by aqueous vapour when it returns to the state of water. This process is *condensation*, the reverse of evaporation. When vapour exists in the atmosphere, if in any manner the temperature becomes lower than the *constituent temperature*, requisite for the maintenance of the vapoury state, some of the steam will be condensed and will become water. It is in this manner that the curl of steam from the spout of a boiling tea-kettle becomes visible, being cooled down as it rushes to the air. The steam condenses into a fine watery powder, which is carried about by the little aerial currents. Clouds are of the same nature with such curls, the condensation being generally produced when air, charged with aqueous vapour, is mixed with a colder current, or has its temperature diminished in any other manner.

Clouds, while they retain that shape, are of the most essential use to vegetable and animal life. They moderate the fervour of the sun, in a manner agreeable, to a greater or less degree, in all climates, and grateful no less to vegetables than to animals. Duhamel says that plants grow more during a week of cloudy weather than a month of dry and hot. It has been observed that vegetables are far more refreshed by being watered in cloudy than in clear weather. In the latter case, probably the supply of fluid is too rapidly carried off by evaporation. Clouds also moderate the alternations of temperature, by checking the radiation from the earth. The coldest nights are those which occur under a cloudless winter sky.

The uses of clouds, therefore, in this stage of their history, are by no means inconsiderable, and seem to indicate to us that the laws of their formation were constructed with a view to the purposes of organized life.

5. Clouds produce *rain*. In the formation of a cloud the precipitation of moisture probably forms a fine watery *powder*, which remains suspended in the air in consequence of the minuteness of its particles: but if from any cause the precipitation is collected in larger portions, and becomes *drops*, these descend by their weight and produce a shower.

However rain is formed, it is one of the consequences of the capacity of evaporation and condensation which belongs to water, and its uses are the result of the laws of those processes. Its uses to plants are too obvious and too numerous to be described. It is evident that on its quantity and distribution depends in a great measure the prosperity of the vegetable kingdom: and different climates

are fitted for different productions, no less by the relations of dry weather and showers, than by those of hot and cold.

6. Returning back still further in the changes which cold can produce on water, we come to *snow* and *ice:* snow being apparently frozen vapour, aggregated by a confused action of crystalline laws; and ice being water in its fluid state, solidified by the same crystalline forces. The impression of these agents on the animal feelings is generally unpleasant, and we are in the habit of considering them as symptoms of the power of winter to interrupt that state of the elements in which they are subservient to life. Yet, even in this form, they are not without their uses.* "Snow and ice are bad conductors of cold; and when the ground is covered with snow, or the surface of the soil or of water is frozen, the roots or bulbs of plants beneath are protected by the congealed water from the influence of the atmosphere, the temperature of which, in northern winters, is usually very much below the freezing point; and this water becomes the first nourishment of the plant in early spring. The expansion of water during its congelation, at which time its volume increases one-twelfth, and its contraction in bulk during a thaw, tend to pulverize the soil, to separate its parts from each other, and to make it more permeable to the influence of the air." In consequence of the same slowness in the conduction of heat which snow thus possesses, the arctic traveller finds his bed of snow of no intolerable coldness; the Esquimaux is sheltered from the inclemency of the season in his snow hut, and travels rapidly and agreeably over the frozen surface of the sea. The uses of those arrangements, which at first appear productive only of pain and inconvenience, are well suited to give confidence and hope to our researches for such usefulness in every part of the creation. They have thus a peculiar value in adding connexion and universality to our perception of beneficial design.

7. There is a peculiar circumstance still to be noticed in the changes from ice to water and from water to steam. These changes take place at a particular and invariable degree of heat; yet they do not take place suddenly when we increase the heat to this degree. This is a very curious arrangement. The temperature *makes a stand*, as it were, at the point where thaw, and where boiling take place. It is necessary to apply a considerable quantity of heat to produce these effects; all which heat disappears, or becomes *latent*, as it is called. We cannot raise the temperature of a thawing mass of ice till we have thawed the whole. We cannot raise the temperature of boiling water, or of steam rising from it, till we have converted all the water into steam. Any heat that we apply while these changes are going on is absorbed in producing the changes.

The consequences of this property of *latent heat* are very impor-

* Loudon, 1214.

tant. It is on this account that the changes now spoken of necessarily occupy a considerable time. Each part in succession must have a proper degree of heat applied to it. If it were otherwise, thaw and evaporation must be instantaneous: at the first touch of warmth, all the snow which lies on the roofs of our houses would descend like a water-spout into the streets: all that which rests on the ground would rush like an inundation into the water-courses. The hut of the Esquimaux would vanish like a house in a pantomime: the icy floor of the river would be gone without giving any warning to the skaiter or the traveller: and when, in heating our water, we reached the boiling point, the whole fluid would "flash into steam," (to use the expression of engineers,) and dissipate itself in the atmosphere, or settle in dew on the neighbouring objects.

It is obviously necessary for the purposes of human life, that these changes should be of a more gradual and manageable kind than such as we have now described. Yet this gradual progress of freezing and thawing, of evaporation and condensation, is produced, so far as we can discover, by a particular contrivance. Like the freezing of water from the top, or the floating of ice, the moderation of the rate of these changes seems to be the result of a *violation* of a law: that is, the simple rule regarding the effects of change of temperature, which at first sight appears to be the law, and which, from its simplicity, would seem to us the most obvious law for these as well as other cases, is modified at certain critical points, *so as to* produce these advantageous effects:—why may we not say *in order to* produce such effects?

8. Another office of water which it discharges by means of its relations to heat, is that of supplying our *springs*. There can be no doubt that the old hypotheses which represent springs as drawing their supplies from large subterranean reservoirs of water, or from the sea by a process of subterraneous filtration, are erroneous and untenable. The quantity of evaporation from water and from wet ground is found to be amply sufficient to supply the requisite drain. Mr. Dalton calculated* that the quantity of rain which falls in England is thirty-six inches a year. Of this he reckoned that thirteen inches flow off to the sea by the rivers, and that the remaining twenty-three inches are raised again from the ground by evaporation. The thirteen inches of water are of course supplied by evaporation from the sea, and are carried back to the land through the atmosphere. Vapour is perpetually rising from the ocean, and is condensed in the hills and high lands, and through their pores and crevices descends, till it is deflected, collected, and conducted out to the day, by some stratum or channel which is watertight. The condensation which takes place in the higher parts of a country, may easily be recognised in the mists and rains which are the frequent occu-

* Manchester Memoirs, v. 357.

pants of such regions. The coldness of the atmosphere and other causes precipitate the moisture in clouds and showers, and in the former as well as in the latter shape, it is condensed and absorbed by the cold ground. Thus a perpetual and compound circulation of the waters is kept up; a narrower circle between the evaporation and precipitation of the land itself, the rivers and streams only occasionally and partially forming a portion of the circuit; and a wider interchange between the sea and the lands which feed the springs, the water ascending perpetually by a thousand currents through the air, and descending by the gradually converging branches of the rivers, till it is again returned into the great reservoir of the ocean.

In every country, these two portions of the aqueous circulation have their regular, and nearly constant, proportion. In this kingdom the relative quantities are, as we have said, 23 and 13. A due distribution of these circulating fluids in each country appears to be necessary to its organic health; to the habits of vegetables, and of man. We have every reason to believe that it is kept up from year to year as steadily as the circulation of the blood in the veins and arteries of man. It is maintained by a machinery very different, indeed, from that of the human system, but apparently as well, and, therefore, we may say as clearly, as that, adapted to its purposes.

By this machinery, we have a connexion established between the atmospheric changes of remote countries. Rains in England are often introduced by a south-east wind. "Vapour brought to us by such a wind, must have been generated in countries to the south and east of our island. It is therefore, probably, in the extensive valleys watered by the Meuse, the Moselle, and the Rhine, if not from the more distant Elbe, with the Oder and the Weser, that the water rises, in the midst of sunshine, which is soon afterwards to form *our* clouds, and pour down *our* thunder-showers." "Draught and sunshine in one part of Europe may be as necessary to the production of a wet season in another, as it is on the great scale of the continents of Africa and South America; where the plains, during one half the year, are burnt up, to feed the springs of the mountains; which in their turn contribute to inundate the fertile valleys and prepare them for a luxuriant vegetation."* The properties of water which regard heat make one vast *watering-engine* of the atmosphere.

* Howard on the Climate of London, vol. ii. pp. 216, 217.

CHAPTER X.

THE LAWS OF HEAT WITH RESPECT TO AIR.

We have seen in the preceding chapter how many and how important are the offices discharged by the aqueous part of the atmosphere. The aqueous part is, however, a very small part only: it may vary, perhaps, from less than 1-100th to nearly as much as 1-20th in weight, of the whole aerial ocean. We have to offer some considerations with regard to the remainder of the mass.

1. In the first place we may observe that the aerial atmosphere is necessary as a vehicle for the aqueous vapour. Salutary as is the operation of this last element to the whole organized creation, it is a substance which would not have answered its purposes if it had been administered pure. It requires to be diluted and associated with dry air, to make it serviceable. A little consideration will show this.

We can suppose the earth with no atmosphere except the vapour which arises from its watery parts: and if we suppose also the equatorial parts of the globe to be hot, and the polar parts cold, we may easily see what would be the consequence. The waters at the equator, and near the equator, would produce steam of greater elasticity, rarity, and temperature, than that which occupies the regions further *polewards;* and such steam, as it came in contact with the colder vapour of a higher latitude, would be precipitated into the form of water. Hence there would be a perpetual current of steam from the equatorial parts towards each pole, which would be condensed, would fall to the surface, and flow back to the equator in the form of fluid. We should have a circulation which might be regarded as a species of regulated distillation.* On a globe so constituted, the sky of the equatorial zone would be perpetually cloudless; but in all other latitudes we should have an uninterrupted shroud of clouds, fogs, rains, and, near the poles, a continual fall of snow. This would be balanced by a constant flow of the currents of the ocean from each pole towards the equator. We should have an excessive circulation of moisture, but no sunshine, and probably only minute changes in the intensity and appearances of one eternal drizzle or shower.

It is plain that this state of things would but ill answer the ends of vegetable and animal life: so that even if the lungs of animals and the leaves of plants were so constructed as to breathe steam instead of air, an atmosphere of unmixed steam would deprive those creatures of most of the other external conditions of their well-being.

The real state of things which we enjoy, the steam being mixed in our breath and in our sky in a moderate quantity, gives rise to re-

* Daniell. Meteor. Ess. p. 56.

sults very different from those which have been described. The machinery by which these results are produced is not a little curious. It is in fact the machinery of the *weather*, and therefore the reader will not be surprised to find it both complex and apparently uncertain in its working. At the same time some of the general principles which govern it seem now to be pretty well made out, and they offer no small evidence of beneficent arrangement.

Besides our atmosphere of aqueous vapour, we have another and far larger atmosphere of common air; a *permanently elastic* fluid, that is, one which is not condensed into a liquid form by pressure or cold, such as it is exposed to in the order of natural events. The pressure of the dry air is about $29\frac{1}{2}$ inches of mercury; that of the watery vapour, perhaps, half an inch. Now if we had the earth quite dry, and covered with an atmosphere of dry air, we can trace in a great measure what would be the results, supposing still the equatorial zone to be hot, and the temperature of the surface to decrease perpetually as we advance into higher latitudes. The air at the equator would be rarefied by the heat, and would be perpetually displaced below by the denser portions which belonged to cooler latitudes. We should have a current of air from the equator to the poles in the higher regions of the atmosphere, and at the surface a returning current setting towards the equator to fill up the void so created. Such aerial currents, combined with the rotatory motion of the earth, would produce oblique winds; and we have in fact instances of winds so produced, in the trade winds, which between the tropics blow constantly from the quarters between east and north, and are, we know, balanced by opposite currents in higher regions. The effect of a heated surface of land would be the same as that of the heated zone of the equator, and would attract to it a sea breeze during the day time, a phenomenon, as we also know, of perpetual occurrence.

Now a mass of dry air of such a character as this, is by far the dominant part of our atmosphere; and hence carries with it in its motions the thinner and smaller eddies of aqueous vapour. The latter fluid may be considered as permeating and moving in the interstices of the former, as a spring of water flows through a sand rock.* The lower current of air is, as has been said, directed towards the equator, and hence it resists the motion of the steam, the tendency of which is in the opposite direction; and prevents or much retards that continual flow of hot vapour into colder regions, by which a constant precipitation would take place in the latter situations.

If, in this state of things, the flow of the current of air, which blows from any colder place into a warmer region, be retarded or stopped, the aqueous vapours will now be able to make their way

* Daniell. p. 129.

to the colder point, where they will be precipitated in clouds or showers.

Thus, in the lower part of the atmosphere, there are tendencies to a current of air in one direction, and a current of vapour in the opposite; and these tendencies exist in the average weather of places situated at a moderate distance from the equator. The air tends from the colder to the warmer parts, the vapour from the warmer to the colder.

The various distribution of land and sea, and many other causes, make these currents far from simple. But in general the air current predominates, and keeps the skies clear and the moisture dissolved. Occasional and irregular occurrences disturb this predominance; the moisture is then precipitated, the skies are clouded, and the clouds may descend in copious rains.

These alternations of fair weather and showers appear to be much more favourable to vegetable and animal life than any uniform course of weather could have been. To produce this variety, we have two antagonist forces, by the struggle of which such changes occur. Steam and air, two transparent and elastic fluids, expansible by heat, are in many respects and properties very like each other. Yet, the same heat similarly applied to the globe, produces at the surface currents of these fluids, tending in opposite directions. And these currents mix and balance, conspire and interfere, so that our trees and fields have alternately water and sunshine; our fruits and grain are successively developed and matured. Why should such laws of heat and elastic fluids so obtain, and be so combined? Is it not in order that they may be fit for such offices? There is here an arrangement, which no chance could have produced. The details of this apparatus may be beyond our power of tracing; its springs may be out of our sight. Such circumstances do not make it less a curious and beautiful contrivance: they need not prevent our recognising the skill and benevolence which we *can* discover.

2. But we have not yet done with the machinery of the weather. In ascending from the earth's surface through the atmosphere, we find a remarkable difference in the heat and in the pressure of the air. It becomes much colder, and much lighter; men's feelings tell them this; and the thermometer and barometer confirm these indications. And here again we find something to remark.

In both the simple atmospheres of which we have spoken, the one of air and the one of steam, the property which we have mentioned must exist. In each of them, both the temperature and the tension would diminish in ascending. But they would diminish at very different rates. The temperature, for instance, would decrease much more rapidly for the same height in dry air than in steam. If we begin with a temperature of 80 degrees at the surface, on ascending 5,000 feet the steam is still $76\frac{1}{2}$ degrees, the air is only $64\frac{1}{2}$ degrees; at 10,000 feet, the steam is 73 degrees, the air $48\frac{1}{2}$ degrees: at

15,000 feet, steam is at 70 degrees, air has fallen below the freezing point to $31\frac{1}{2}$ degrees. Hence these two atmospheres cannot exist together without modifying one another: one must heat or cool the other, so that the coincident parts may be of the same temperature. This accordingly does take place, and this effect influences very greatly the constitution of the atmosphere. For the most part, the steam is compelled to accommodate itself to the temperature of the air, the latter being of much the greater bulk. But if the upper parts of the aqueous vapour be cooled down to the temperature of the air, they will not by any means exert on the lower parts of the same vapour so great a pressure as the gaseous form of these could bear. Hence, there will be a deficiency of moisture in the lower part of the atmosphere, and if water exist there, it will rise by evaporation, the surface feeling an insufficient tension; and there will thus be a fresh supply of vapour upwards. As, however, the upper regions already contain as much as their temperature will support in the state of gas, a precipitation will now take place, and the fluid thus formed will descend till it arrives in a lower region, where the tension and temperature are again adapted to its evaporation.

Thus, we can have no equilibrium in such an atmosphere, but a perpetual circulation of vapour between its upper and lower parts. The currents of air which move about in different directions, at different altitudes, will be differently charged with moisture, and as they touch and mingle, lines of cloud are formed, which grow and join, and are spread out in floors, or rolled together in piles. These, again, by an additional accession of humidity, are formed into drops, and descend in showers into the lower regions, and if not evaporated in their fall, reach the surface of the earth.

The varying occurrences thus produced, tend to multiply and extend their own variety. The ascending streams of vapour carry with them that *latent heat* belonging to their gaseous state, which, when they are condensed, they give out as sensible heat. They thus raise the temperature of the upper regions of air, and occasion changes in the pressure and motion of its currents. The clouds, again, by shading the surface of the earth from the sun, diminish the evaporation by which their own substance is supplied, and the heating effects by which currents are caused. Even the mere mechanical effects of the currents of fluid on the distribution of its own pressure, and the dynamical conditions of its motion, are in a high degree abstruse in their principles and complex in their results. It need not be wondered, therefore, if the study of this subject is very difficult and entangled, and our knowledge, after all, very imperfect.

In the middle of all this apparent confusion, however, we can see much that we can understand. And, among other things, we may notice some of the consequences of the difference of the laws of temperature followed by steam and by air in going upwards. One

important result is that the atmosphere is much drier, near the surface, than it would have been if the laws of density and temperature had been the same for both gases. If this had been so, the air would always have been *saturated* with vapour. It would have contained as much as the existing temperature could support, and the slightest cooling of any object would have covered it with a watery film like dew. As it is, the air contains much less than its full quantity of vapour: we may often cool an object 10, 20, or 30 degrees without obtaining a deposition of water upon it, or reaching the *dew-point,* as it is called. To have had such a *dripping* state of the atmosphere as the former arrangement would have produced, would have been inconvenient, and so far as we can judge, unsuited to vegetables as well as animals. No evaporation from the surface of either could have taken place under such conditions.

The sizes and forms of clouds appear to depend on the same circumstance, of the air not being saturated with moisture. And it is seemingly much better that clouds should be comparatively small and well defined, as they are, than that they should fill vast depths of the atmosphere with a thin mist, which would have been the consequence of the imaginary condition of things just mentioned.

Here then we have another remarkable exhibition of two laws, in two nearly similar gaseous fluids, producing effects alike in kind, but different in degree, and by the *play* of their difference giving rise to a new set of results, peculiar in their nature and beneficial in their tendency. The *form* of the laws of air and of steam with regard to heat might, so far as we can see, have been more similar, or more dissimilar, than it now is: the rate of each law might have had a different amount from its present one, so as quite to alter the relation of the two. By the laws having such forms and such rates as they have, effects are produced, some of which we can distinctly perceive to be beneficial. Perhaps most persons will feel a strong persuasion, that if we understood the operation of these laws more distinctly, we should see still more clearly the beneficial tendency of these effects, and should probably discover others, at present concealed in the apparent perplexity of the subject.

3. From what has been said, we may see, in a general way, both the causes and the effects of *winds.* They arise from any disturbance by temperature, motion, pressure, &c. of the equilibrium of the atmosphere, and are the efforts of nature to restore the balance. Their office in the economy of nature is to carry heat and moisture from one tract to another, and they are the great agents in the distribution of temperature and the changes of weather. Other purposes might easily be ascribed to them in the business of the vegetable and animal kingdoms, and in the arts of human life, of which we shall not here treat. That character in which we now consider them, that of the machinery of atmospheric changes, and

thus, immediately or remotely, the instruments of atmospheric influences, cannot well be refused them by any person.

4. There is still one reflection which ought not to be omitted. All the changes of the weather, even the most violent tempests and torrents of rain, may be considered as oscillations about the mean or average condition belonging to each place. All these oscillations are limited and transient; the storm spends its fury, the inundation passes off, the sky clears, the calmer course of nature succeeds. In the forces which produce this derangement, there is a provision for making it short and moderate. The oscillation stops of itself, like the rolling of a ship, when no longer impelled by the wind. Now, why should this be so? Why should the oscillations, produced by the conflict of so many laws, seemingly quite unconnected with each other, be of this converging and subsiding character? Would it be so under all arrangements? Is it a matter of mechanical necessity that disturbance must end in the restoration of the medium condition? By no means. There may be an utter subversion of the equilibrium. The ship may roll too far, and may *capsize.* The oscillations may go on, becoming larger and larger, till all trace of the orginal condition is lost; till new forces of inequality and disturbance are brought into play; and disorder and irregularity may succeed, without apparent limit or check in its own nature, like the spread of a conflagration in a city. This is a possibility in any combination of mechanical forces; why does it not happen in the one now before us? By what good fortune are the powers of heat, of water, of steam, of air, the effects of the earth's annual and diurnal motions, and probably other causes, so adjusted, that through all their struggles the elemental world goes on, upon the whole, so quietly and steadily? Why is the whole fabric of the weather never utterly deranged, its balance lost irrecoverably? Why is there not an eternal conflict, such as the poets imagine to take place in their chaos?

> "For Hot, Cold, Moist, and Dry, four champions fierce,
> Strive here for mastery, and to battle bring
> Their embryon atoms :—
> to whom these most adhere,
> He rules *a moment:* Chaos umpire sits,
> And by decison more embroils the fray."*

A state of things something like that which Milton here seems to have imagined, is, so far as we know, not mechanically impossible. It might have continued to obtain, if Hot and Cold, and Moist and Dry had not been compelled to "run into their places." It will be hereafter seen, that in the comparatively simple problem of the solar system, a number of very peculiar adjustments were requisite,

* Par. Lost, b. II.

in order that the system might retain a permanent form, in order that its motions might have their cycles, its perturbations their limits and period. The problem of the continuation of such laws and materials as enter into the constitution of the atmosphere, is one manifestly of much greater complexity, and indeed to us probably of insurmountable difficulty as a mechanical problem. But all that investigation and analogy teach us, tends to show that it will resemble the other problem in the nature of its result; and that certain relations of its data, and of the laws of its elements, are necessary requisites, for securing the stability of its mean condition, and for giving a small and periodical character to its deviations from such a condition.

It would then be probable, from this reflexion alone, that in determining the quantity and the law and intensity of the forces, of earth, water, air, and heat, the same regard has been shown to the permanency and stability of the terrestrial system, which may be traced in the adjustment of the masses, distances, positions, and motions of the bodies of the celestial machine.

This permanency appears to be, of itself, a suitable object of contrivance. The purpose for which the world was made could be answered only by its being preserved. But it has appeared, from the preceding part of this and the former chapter, that this permanence is a permanence of a state of things adapted by the most remarkable and multiplied combinations to the well-being of man, of animals, of vegetables. The adjustments and conditions therefore, beyond the reach of our investigation, as they are, by which its permanence is secured, must be conceived as fitted to add, in each of the instances above adduced, to the admiration which the several manifestations of Intelligent Beneficence are calculated to excite.

CHAPTER XI.

THE LAWS OF ELECTRICITY.

Electricity undoubtedly exists in the atmosphere in most states of the air; but we know very imperfectly the laws of this agent, and are still more ignorant of its atmospheric operation. The present state of science does not therefore enable us to perceive those adaptations of its laws to its uses, which we can discover in those cases where the laws and the uses are both of them more apparent.

We can, however, easily make out that electrical agency plays a very considerable part among the clouds, in their usual conditions

and changes. This may be easily shown by Franklin's experiment of the electrical kite. The clouds are sometimes positively, sometimes negatively, charged, and the rain which descends from them offers also indications of one or other kind of electricity. The changes of wind and alterations of the form of the clouds are generally accompanied with changes in these electrical indications. Every one knows that a thunder-cloud is strongly charged with the electric fluid, (if it be a fluid,) and that the stroke of the lightning is an electrical discharge. We may add that it appears, by recent experiments, that a transfer of electricity between plants and the atmosphere is perpetually going on during the process of vegetation.

We cannot trace very exactly the precise circumstances, in the occurrences of the atmospheric regions, which depend on the influence of the laws of electricity: but we are tolerably certain, from what has been already noticed, that if these laws did not exist, or were very different from what they now are, the action of the clouds and winds, and the course of vegetation, would also be other than it now is.

It is therefore at any rate very probable that electricity has its appointed and important purposes in the economy of the atmosphere. And this being so, we may see a use in the thunderstorm and the stroke of the lightning. These violent events are, with regard to the electricity of the atmosphere, what winds are with regard to heat and moisture. They restore the equilibrium where it has been dissolved, and carry the fluid from places where it is superfluous, to others where it is deficient.

We are so constituted, however, that these crises impress almost every one with a feeling of awe. The deep lowering gloom of the thunder-cloud, the overwhelming burst of the explosion, the flash from which the steadiest eye shrinks, and the irresistible arrow of the lightning which no earthly substance can withstand, speak of something fearful, even independently of the personal danger which they may whisper. They convey, far more than any other appearance does, the idea of a superior and mighty power, manifesting displeasure and threatening punishment. Yet we find that this is not the language which they speak to the physical inquirer: he sees these formidable symptoms only as the means or the consequences of good. What office the thunderbolt and the whirlwind may have in the *moral* world, we cannot here discuss: but certainly *he* must speculate as far beyond the limits of philosophy as of piety, who pretends to have learnt that there their work has more of evil than of good. In the *natural* world, these apparently destructive agents are, like all the other movements and appearances of the atmosphere, parts of a great scheme, of which every discoverable purpose is marked with beneficence as well as wisdom.

CHAPTER XII.

THE LAWS OF MAGNETISM.

Magnetism has no very obvious or apparently extensive office in the mechanism of the atmosphere and the earth: but the mention of it may be introduced, because its ascertained relations to the other powers which exist in the system are well suited to show us the connexion subsisting throughout the universe, and to check the suspicion, if any such should arise, that any law of nature is without its use. The parts of creation when these uses are most obscure, are precisely those parts when the laws themselves are least known.

When indeed we consider the vast service of which magnetism is to man, by supplying him with that invaluable instrument the mariner's compass, many persons will require no further evidence of this property being introduced into the frame of things with a worthy purpose. As however, we have hitherto excluded *use in the arts* from our line of argument, we shall not here make an exception in favour of navigation, and what we shall observe belongs to another view of the subject.

Magnetism has been discovered in modern times to have so close a connexion with galvanism, that they may be said to be almost different aspects of the same agent. All the phenomena which we can produce with magnets, we can imitate with coils of galvanic wire. That galvanism exists in the earth, we need no proof. Electricity, which appears to be only galvanism in equilibrium, is there in abundance; and recently, Mr. Fox* has shown by experiment that metalliferous veins, as they lie in the earth, exercise a galvanic influence on each other. Something of this kind might have been anticipated; for masses of metal in contact, if they differ in temperature or other circumstances, are known to produce a galvanic current. Hence we have undoubtedly streams of galvanic influence moving along in the earth. Whether or not such causes as these produce the directive power of the magnetic needle, we cannot here pretend to decide; they can hardly fail to affect it. The Aurora Borealis too, probably an electrical phenomenon, is said, under particular circumstances, to agitate the magnetic needle. It is not surprising, therefore, that, if electricity have an important office in the atmosphere, magnetism should exist in the earth. It seems likely, that the magnetic properties of the earth may be collateral results of the existence of the same cause by which electrical agency operates; an agency which, as we have already seen, has important offices in the processes of

* Phil. Trans. 1831.

vegetable life. And thus magnetism belongs to the same system of beneficial contrivance to which electricity has been already traced.

We see, however, on this subject very dimly and a very small way. It cay hardly be doubted that magnetism has other functions than those we have noticed.

CHAPTER XIII.

THE PROPERTIES OF LIGHT WITH REGARD TO VEGETATION.

The illuminating power of light will come under our consideration hereafter. Its agency, with regard to organic life, is too important not to be noticed, though this must be done briefly. Light appears to be as necessary to the health of plants as air or moisture. A plant may, indeed, grow without it, but it does not appear that a species could be so continued. Under such a privation, the parts which are usually green, assume a white colour, as is the case with vegetables grown in a cellar, or protected by a covering for the sake of producing this very effect; thus, celery is in this manner blanched, or *etiolated.*

The part of the process of vegetable life for which light is especially essential, appears to be the functions of the leaves; these are affected by this agent in a very remarkable manner. The moisture which plants imbibe is, by their vital energies, carried into their leaves; and is then brought in contact with the atmosphere, which, besides other ingredients, contains, in general, a portion of carbonic acid. *So long as light is present,* the leaf decomposes the carbonic acid, appropriates the carbon to the formation of its own proper juices, and returns the disengaged oxygen into the atmosphere; thus restoring the atmospheric air to a condition in which it is more fitted than it was before for the support of animal life. The plant thus prepares the support of life for other creatures at the same time that it absorbs its own. The greenness of those members which affect that colour, and the disengagement of oxygen, are the indications that its vital powers are in healthful action: as soon as we remove light from the plant, these indications cease: it has no longer power to imbibe carbon and disengage oxygen, but on the contrary, it gives back some of the carbon already obtained, and robs the atmosphere of oxygen for the purpose of reconverting this into carbonic acid.

It cannot well be conceived that such effects of light on vegetables, as we have described, should occur, if that agent, of whatever nature it is, and those organs, had not been adapted to each other. But this subject is here introduced that the reader may the more readily re-

ceive the conviction of combining purpose which must arise, on finding that an agent, possessing these very peculiar chemical properties, is employed to produce also those effects of illumination, vision, &c., which form the most obvious portion of the properties of light.

CHAPTER XIV.

SOUND.

Besides the function which air discharges as the great agent in the changes of meteorology and vegetation, it has another office, also of great and extensive importance, as the vehicle of sound.

1. The communication of sound through the air takes place by means of a process altogether different from anything of which we have yet spoken: namely, by the propagation of minute *vibrations* of the particles from one part of the fluid mass to another, without any local motion of the fluid itself.

Perhaps we may most distinctly conceive the kind of effect here spoken of, by comparing it to the motion produced by the wind in a field of standing corn; grassy waves travel visibly over the field, in the direction in which the wind blows, but this appearance of an object moving is delusive. The only real motion is that of the ears of grain, of which each goes and returns, as the stalk stoops and recovers itself. This motion affects *successively* a line of ears in the direction of the wind, and affects *simultaneously* all those ears of which the elevation or depression forms one visible wave. The elevations and depressions are propagated in a constant direction, while the parts with which the space is filled only vibrate to and fro. Of exactly such a nature is the propagation of sound through the air. The particles of air go and return through very minute spaces, and this vibratory motion runs through the atmosphere from the sounding body to the ear. Waves, not of elevation and depression, but of condensation and rarefaction, are transmitted; and the sound thus becomes an object of sense to the organ.

Another familiar instance of the propagation of vibrations we have in the circles on the surface of smooth water, which diverge from the point where it is touched by a small object, as a drop of rain. In the beginning of a shower for instance, when the drops come distinct, though frequent, we may see each drop giving rise to a ring, formed of two or three close concentric circles, which grow and spread, leaving the interior of the circle smooth, and gradually reaching parts of the surface more and more distant from their origin. In this instance, it is clearly not a portion of the water which flows on-

wards; but the disturbance, the rise and fall of the surface which makes the ring-formed waves, passes into wider and wider circles, and thus the undulation is transmitted from its starting-place, to points in all directions on the surface of the fluid.

The diffusion of these ring-formed undulations from their centre resembles the diffusion of a sound from the place where it is produced to the points where it is heard. The disturbance, or vibration, by which it is conveyed, travels at the same rate in all directions, and the waves which are propagated are hence of a circular form. They differ, however, from those on the surface of water; for sound is communicated upwards and downwards, and in all intermediate directions, as well as horizontally; hence the waves of sound are spherical, the point where the sound is produced being the centre of the sphere.

This diffusion of vibrations in spherical shells of successive condensation and rarefaction, will easily be seen to be different from any local motion of the air, as wind, and to be independent of that. The circles on the surface of water will spread on a river which is flowing, provided it be smooth, as well as on a standing canal.

Not only are such undulations propagated almost undisturbed by any local motion of the fluid in which they take place, but also, many may be propagated in the same fluid at the same time, without disturbing each other. We may see this effect on water. When several drops fall near each other, the circles which they produce cross each other, without either of them being lost, and the separate courses of the rings may still be traced.

All these consequences, both in water, in air, and in any other fluid, can be very exactly investigated upon mechanical principles, and the greater part of the phenomena can thus be shown to result from the properties of the fluids.

There are several remarkable circumstances in the way in which air answers its purpose as the vehicle of sound, of which we will now point out a few.

2. The *loudness* of sound is such as is convenient for common purposes. The organs of speech can, in the present constitution of the air, produce, without fatigue, such a tone of voice as can be heard with distinctness and with comfort. That any great alteration in this element might be incommodious, we may judge from the difficulties to which persons are subject who are dull of hearing, and from the disagreeable effects of a voice much louder than usual, or so low as to be indistinct. Sounds produced by the human organs, with other kinds of air, are very different from those in our common air. If a man inhale a quantity of hydrogen gas, and then speak, his voice is scarcely audible.

The loudness of sounds become smaller in proportion as they come from a greater distance. This enables us to judge of the distance of objects, in some degree at least, by the sounds which proceed from them. Moreover it is found that we can judge of the

position of objects by the ear: and this judgment seems to be formed by comparing the loudness of the impression of the same sound on the two ears and two sides of the head.*

The loudness of sounds appears to depend on the *extent* of vibration of the particles of air, and this is determined by the vibrations of the sounding body.

3. The *pitch*, or the *differences of acute and grave*, in sounds, form another important property, and one which fits them for a great part of their purposes. By the succession of different *notes*, we have all the results of melody and harmony in musical sound; and of intonation and modulation of the voice, of accent, cadence, emphasis, expression, passion, in speech. The song of birds, which is one of their principal modes of communication, depends chiefly for its distinctions and its significance upon the combinations of acute and grave.

These differences are produced by the different *rapidity* of vibration of the particles of air. The gravest sound has about eighty vibrations in a second, the most acute about one thousand. Between these limits each sound has a musical character, and from the different relations of the number of vibrations in a second arise all the differences of musical intervals, concords and discords.

4. The *quality* of sounds is another of their differences. This is the name given to the difference of notes of the same pitch, that is the same note as to acute and grave, when produced by different instruments. If a flute and a violin be in unison, the notes are still quite different sounds. It is this kind of difference which distinguishes the voice of one man from that of another: and it is manifestly therefore one of great consequence; since it connects the voice with the particular person, and is almost necessary in order that language may be a medium of intercourse between men.

5. The *articulate* character of sounds is for us one of the most important arrangements which exist in the world; for it is by this that they become the interpreters of thought, will and feeling, the means by which a person can convey his wants, his instructions, his promises, his kindness, to others; by which one man can regulate the actions and influence the convictions and judgments of another. It is in virtue of the possibility of shaping air into words, that the imperceptible vibrations which a man produces in the atmosphere, become some of his most important actions; the foundations of the highest moral and social relations; and the condition and instrument of all the advancement and improvement of which he is susceptible.

It appears that the differences of articulate sound arise from the different form of the cavity through which the sound is made to proceed immediately *after* being produced. In the human voice

* Mr. Gough in Manch. Mem. vol. v.

the sound is produced in the larynx, and modified by the cavity of the mouth, and the various organs which surround this cavity. The laws by which articulate sounds are thus produced have not yet been fully developed, but appear to be in the progress of being so.

The properties of sounds which have been mentioned, differences of loudness, of pitch, of quality, and articulation, appear to be all requisite in order that sound shall answer its purposes in the economy of animal and of human life. And how was the air made capable of conveying these four differences, at the same time that the organs were made capable of producing them? Surely by a most refined and skilful adaptation, applied with a most comprehensive design.

6. Again; is it by chance that the air and the *ear* exist together? Did the air produce the organization of the ear? or the ear, independently organized, anticipate the constitution of the atmosphere? Or is not the only intelligible account of the matter, this, that one was made for the other: that there is a mutual adaptation produced by an Intelligence which was acquainted with the properties of both; which adjusted them to each other as we find them adjusted, in order that birds might communicate by song, that men might speak and hear, and that language might play its extraordinary part in its operation upon men's thoughts, actions, institutions, and fortunes?

The vibrations of an elastic fluid like the air, and their properties, follow from the laws of motion; and whether or not these laws of the motion of fluids might in reality have been other than they are, they appear to us inseparably connected with the existence of matter, and as much a thing of necessity as we can conceive anything in the universe to be. The propagation of such vibrations, therefore, and their properties, we may at present allow to be a necessary part of the constitution of the atmosphere. But what is it that makes these vibrations become sound? How is it that they produce such an effect on our senses, and, through those, on our minds? The vibrations of the air seem to be of themselves no more fitted to produce sound, than to produce smell. We know that such vibrations do not universally produce sound, but only between certain limits. When the vibrations are fewer than eighty in a second, they are perceived at separate throbs, and not as a continued sound; and there is a certain limit of rapidity, beyond which the vibrations become inaudible. This limit is different to different ears, and we are thus assured by one person's ear that there are vibrations, though to that of another they do not produce sound. How was the human ear adapted so that its perception of vibrations as sounds should fall within these limits?—the very limits within which the vibrations fall, which it most concerns us to perceive: those of the human voice for instance? How nicely are the organs adjusted with regard to the most minute mechanical motions of the elements!

CHAPTER XV.

THE ATMOSPHERE.

We have considered in succession a number of the properties and operations of the atmosphere, and have found them separately very curious. But an additional interest belongs to the subject when we consider them as combined. The atmosphere under this point of view must appear a contrivance of the most extraordinary kind. To answer any of its purposes, to carry on any of its processes, separately, requires peculiar arrangements and adjustments; to answer, all at once, purposes so varied, to combine without confusion so many different trains, implies powers and attributes which can hardly fail to excite in a high degree our admiration and reverence.

If the atmosphere be considered as a vast machine, it is difficult to form any just conception of the profound skill and comprehensiveness of design which it displays. It diffuses and tempers the heat of different climates; for this purpose it performs a circulation occupying the whole range from the pole to the equator; and while it is doing this, it executes many smaller circuits between the sea and the land. At the same time, it is the means of forming clouds and rain, and for this purpose, a perpetual circulation of the watery part of the atmosphere goes on between its lower and upper regions. Besides this complication of circuits, it exercises a more irregular agency, in the occasional winds which blow from all quarters, tending perpetually to restore the equilibrium of heat and moisture. But this incessant and multiplied activity discharges only a part of the functions of the air. It is, moreover, the most important and universal material of the growth and sustenance of plants and animals; and is for this purpose every where present and almost uniform in its quantity. With all its local motion, it has also the office of a medium of communication between intelligent creatures, which office it performs by another set of motions, entirely different both from the circulation and the occasional movements already mentioned; these different kinds of motions not interfering materially with each other: and this last purpose, so remote from the others in its nature, it answers in a manner so perfect and so easy, that we cannot imagine that the object could have been more completely attained, if this had been the sole purpose for which the atmosphere had been created. With all these qualities, this extraordinary part of our terrestrial system is scarcely ever in the way: and when we have occasion to do so, we put forth our hand and push it aside, without being aware of its being near us.

We may add, that it is, in addition to all that we have hitherto noticed, a constant source of utility and beauty in its effects on light. Without air we should see nothing, except objects on which the sun's rays fell, directly or by reflection. It is the atmosphere which converts sunbeams into daylight, and fills the space in which we are with illumination.

The contemplation of the atmosphere, as a machine which answers all these purposes, is well suited to impress upon us the strongest conviction of the most refined, far-seeing, and far-ruling contrivance. It seems impossible to suppose that these various properties were so bestowed and so combined, any otherwise than by a beneficent and intelligent Being, able and willing to diffuse organization, life, health, and enjoyment through all parts of the visible world; possessing a fertility of means which no multiplicity of objects could exhaust, and a discrimination of consequences which no complication of conditions could embarrass.

CHAPTER XVI.

LIGHT.

Besides the hearing and sound there is another mode by which we become sensible of the impressions of external objects, namely, sight and light. This subject also offers some observations bearing on our present purpose.

It has been declared by writers on Natural Theology, that the human eye exhibits such evidence of design and skill in its construction, that no one, who considers it attentively, can resist this impression: nor does this appear to be saying too much. It must, at the same time, be obvious that this construction of the eye could not answer its purposes, except the constitution of light corresponded to it. Light is an element of the most peculiar kind and properties, and such an element can hardly be conceived to have been placed in the universe without a regard to its operation and functions. As the eye is made for light, so light must have been made, at least among other ends, for the eye.

1. We must expect to comprehend imperfectly only the mechanism of the elements. Still, we have endeavoured to show that in some instances the arrangements by which their purposes are effected are, to a certain extent, intelligible. In order to explain, however, in what manner light answers those ends which appear to us its principal ones, we must know something of the nature of light. There have, hitherto, been, among men of science, two pre-

vailing opinions upon this subject: some considering light as consisting in the emission of luminous particles; others accounting for its phenomena by the propagation of vibrations through a highly subtle and elastic *ether*. The former opinion has, till lately, been most generally entertained in this country, having been the hypothesis on which Newton made his calculations; the latter is the one to which most of those persons have been led, who, in recent times, have endeavoured to deduce general conclusions from the newly discovered phenomena of light. Among these persons, the *theory of undulations* is conceived to be established in nearly the same manner, and almost as certainly, as the doctrine of universal gravitation; namely, by a series of laws inferred from numerous facts, which, proceeding from different sets of phenomena, are found to converge to one common view; and by calculations founded upon the theory, which, indicating new and untried facts, are found to agree exactly with experiment.

We cannot here introduce a sketch of the progress by which the phenomena have thus led to the acceptance of the theory of undulations. But this theory appears to have such claims to our assent, that the views which we have to offer with regard to the design exercised in the adaptation of light to its purposes, will depend on the undulatory theory, so far as they depend on theory at all.*

2. The impressions of sight, like those of hearing, differ in intensity and in kind. *Brightness* and *Colour* are the principal differences among visible things, as loudness and pitch are among sounds. But there is a singular distinction between these senses in one respect: every object and part of an object seen, is necessarily and inevitably referred to some *position* in the space before us; and hence visible things have place, magnitude, form, as well as light, shade, and colour. There is nothing analogous to this in the sense of hearing; for though we can, in some approximate degree, *guess* the situation of the point from which a sound proceeds, this is a secondary process, distinguishable from the perception of the sound itself; whereas we cannot conceive visible things without form and place.

The law according to which the sense of vision is thus affected, appears to be this. By the properties of light, the external scene produces, through the transparent parts of the eye, an image or picture exactly resembling the reality, upon the back part of the retina: and each point which we see is seen in the direction of a line passing from its image on the retina, through the centre of the

* The reader who is acquainted with the two theories of light, will perceive that though we have adopted the doctrine of the ether, the greater part of the arguments adduced would be equally forcible, if expressed in the language of the theory of emission.

pupil of the eye.* In this manner we perceive by the eye the situation of every point, at the same time that we perceive its existence; and by combining the situations of many points, we have forms and outlines of every sort.

That we should receive from the eye this notice of the position of the object as well as of its other visible qualities, appears to be absolutely necessary for our intercourse with the external world; and the faculty of doing so is so intimate a part of our constitution that we cannot conceive ourselves divested of it. Yet in order to imagine ourselves destitute of this faculty, we have only to suppose that the eye should receive its impressions as the ear does, and should apprehend red and green, bright and dark, without placing them side by side; as the ear takes in the different sounds which compose a concert, without attributing them to different parts of space.

The peculiar property thus belonging to vision, of perceiving position, is so essential to us, that we may readily believe that some particular provision has been made for its existence. The remarkable mechanism of the eye (precisely resembling that of a *camera obscura*,) by which it produces an image on the nervous web forming its hinder part, seems to have this effect for its main object. And this mechanism necessarily supposes certain corresponding properties in light itself, by means of which such an effect becomes possible.

The main properties of light which are concerned in this arrangement, are *reflexion* and *refraction:* reflexion, by which light is reflected and scattered by all objects, and thus comes to the eye from all: and refraction, by which its course is bent, when it passes obliquely out of one transparent medium into another; and by which, consequently, convex transparent substances, such as the cornea and humours of the eye, possess the power of making the light converge to a *focus* or point; an assemblage of such points forming the images on the retina, which we have mentioned.

Reflection and refraction are therefore the essential and indispensable properties of light; and so far as we can understand, it appears that it was necessary that light should possess such properties, in order that it might form a medium of communication between man and the external world. We may consider its power of passing through transparent media (as air) to be given in order that it may enlighten the earth: its affection of reflexion, for the purpose of making colours visible; and its refraction to be bestowed, that it may enable us to discriminate figure and position, by means of the lenses of the eye.

In this manner light may be considered as constituted with a pe-

* Or rather through the *focal centre* of the eye, which is always near the centre of the pupil.

culiar reference to the eyes of animals, and its leading properties may be looked upon as contrivances or adaptations to fit it for its visual office. And in such a point of view the perfection of the contrivance or adaptation must be allowed to be very remarkable.

3. But besides the properties of reflexion and refraction, the most obvious laws of light, an extraordinary variety of phenomena have lately been discovered, regulated by other laws of the most curious kind, uniting great complexity with great symmetry. We refer to the phenomena of diffraction, polarisation, and periodical colours, produced by crystals and by thin plates. We have, in these facts, a vast mass of properties and laws, offering a subject of study which has been pursued with eminent skill and intelligence. But these properties and laws, so far as has yet been discovered, exert no agency whatever, and have no purpose, in the general economy of nature. Beams of light polarised in contrary directions exhibit the most remarkable differences when they pass through certain crystals, but manifest no discoverable difference in their immediate impression on the eye. We have, therefore, here, a number of laws of light, which we cannot perceive to be established with any design which has a reference to the other parts of the universe.

Undoubtedly it is exceedingly possible that these differences of light may operate in some quarter, and in some way, which we cannot detect; and that these laws may have purposes and may answer ends of which we have no suspicion. All the analogy of nature teaches us a lesson of humility, with regard to the reliance which we are to place on our discernment and judgment as to such matters. But with our present knowledge, we may observe, that this curious system of phenomena appears to be a collateral result of the mechanism by which the effects of light are produced; and therefore a necessary consequence of the existence of that element of which the offices are so numerous and so beneficent.

The new properties of light, and the speculations founded upon them, have led many persons to the belief of the undulatory theory; which, as we have said, is considered by some philosophers as demonstrated. If we adopt this theory, we consider the luminiferous ether to have no local motion; and to produce refraction and reflexion by the operation of its elasticity alone. We must necessarily suppose the tenuity of the ether to be extreme; and if we moreover suppose its tension to be very great, which the vast velocity of light requires us to suppose, the vibrations by which light is propagated will be *transverse* vibrations, that is the motion to and fro will be athwart the line along which the undulation travels; and from this circumstance all the laws of polarisation necessarily follow. And the properties of transverse vibrations, combined with the properties of vibrations in general, give rise to all the curious and numerous phenomena of colours of which we have spoken.

If the vibrations be transverse, they may be resolved into two dif-

ferent planes; this is *polarisation:* if they fall on a medium which has different elasticity in different directions, they will be divided into two sets of vibrations; this is *double refraction;* and so on. Some of the new properties, however, as the fringes of shadows and the colours of thin plates, follow from the undulatory theory, whether the vibrations be transverse or not.

It would appear, therefore, that the propagation of light by means of a subtle medium, leads necessarily to the extraordinary collection of properties which have recently been discovered; and, at any rate, its propagation by the transverse vibrations of such a medium does lead inevitably to these results.

Leaving it therefore to future times to point out the other reasons (or *uses* if they exist) of these newly discovered properties of light, in their bearing on other parts of the world, we may venture to say, that if light was to be propagated through transparent media by the undulations of a subtle fluid, these properties must result, as necessarily as the rainbow results from the unequal refrangibility of different colours. This phenomenon and those, appear alike to be the collateral consequences of the laws impressed on light with a view to its principal offices.

Thus the exquisitely beautiful and symmetrical phenomena and laws of polarisation, and of crystalline and other effects, may be looked upon as indications of the delicacy and subtlety of the mechanism by which man, through his visual organs, is put in communication with the external world; is made acquainted with the forms and qualities of objects in the most remote regions of space; and is enabled, in some measure, to determine his position and relation in a universe in which he is but an atom.

4. If we suppose it clearly established that light is produced by the vibrations of an ether, we find considerations offer themselves, similar to those which occurred in the case of sound. The vibrations of this ether affect our organs with the sense of light and colour. Why, or how do they do this? It is only within certain limits that the effect is produced, and these limits are comparatively narrower here than in the case of sound. The whole scale of colour, from violet to crimson, lies between vibrations which are 458 million millions, and 727 million millions in a second; a proportion much smaller than the corresponding ratio for perceptible sounds. Why should such vibrations produce perception in the eye, and no others? There must be here some peculiar adaptation of the sensitive powers to these wonderfully minute and condensed mechanical motions. What happens when the vibrations are slower than the red, or quicker than the blue? They do not produce vision: do they produce any effect? Have they anything to do with heat or with electricity? We cannot tell. The ether must be as susceptible of these vibrations, as of those which produce vision. But the mechanism of the eye is adjusted to this latter kind only; and this precise

kind, (whether alone or mixed with others,) proceeds from the sun and from other luminaries, and thus communicates to us the state of the visible universe. The mere material elements then are full of properties which we can understand no otherwise, than as the results of a refined contrivance.

CHAPTER XVII.

THE ETHER.

In what has just been said, we have spoken of light, only with respect to its power of illuminating objects, and conveying the impression of them to the eye. It possesses, however, beyond all doubt, many other qualities. Light is intimately connected with heat, as we see in the case of the sun and of flame; yet it is clear that light and heat are not identical. Light is evidently connected too with electricity and galvanism; and perhaps, through these, with magnetism: it is, as has already been mentioned, indispensably necessary to the healthy discharge of the functions of vegetable life; without it plants cannot duly exercise their vital powers: it manifests also chemical action in various ways.

The luminiferous *ether* then, if we so call the medium in which light is propagated, must possess many other properties besides those mechanical ones on which the illuminating power depends. It must not be merely like a fluid poured into the vacant spaces and interstices of the material world, and exercising no action on objects; it must affect the physical, chemical and vital powers of what it touches. It must be a great and active agent in the work of the universe, as well as an active reporter of what is done by other agents. It must possess a number of complex and refined contrivances and adjustments which we cannot analyze, bearing upon plants and chemical compounds, and the imponderable agents; as well as those laws which we conceive that we have analyzed, by which it is the vehicle of illumination and vision.

We have had occasion to point out how complex is the machinery of the atmosphere, and how varied its objects; since, besides being the means of communication as the medium of sound, it has known laws which connect it with heat and moisture; and other laws, in virtue of which it is decomposed by vegetables. It appears, in like manner, that the ether is not only the vehicle of light, but has also laws, at present unknown, which connect it with heat, electricity, and other agencies; and other laws through which it is necessary to vegetables, enabling them to decompose air. All analogy

leads us to suppose that if we knew as much of the constitution of the luminiferous ether as we know of the constitution of the atmosphere, we should find it a machine as complex and artificial, as skilfully and admirably constructed.

We know at present very little indeed of the construction of this machine. Its *existence* is, perhaps, satisfactorily made out; in order that we may not interrupt the progress of our argument, we shall refer to other works for the reasonings which appear to lead to this conclusion. But whether heat, electricity, galvanism, magnetism, be fluids; or effects or modifications of fluids; and whether such fluids or *ethers* be the same with the luminiferous ether, or with each other; are questions of which all or most appear to be at present undecided, and it would be presumptuous and premature here to take one side or the other.

The mere fact, however, that there is such an ether, and that it has properties related to other agents, in the way we have suggested, is well calculated to extend our views of the structure of the universe, and of the resources, if we may so speak, of the Power by which it is arranged. The solid and fluid matter of the earth is the most obvious to our senses; over this, and in its cavities, is poured an invisible fluid, the air, by which warmth and life are diffused and fostered, and by which men communicate with men: over and through this again, and reaching, so far as we know, to the utmost bounds of the universe, is spread another most subtle and attenuated fluid, which, by the play of another set of agents, aids the energies of nature, and which, filling all parts of space, is a means of communication with other planets and other systems.

There is nothing in all this like any material necessity, compelling the world to be as it is and no otherwise. How should the properties of these three great classes of agents, visible objects, air, and light, so harmonize and assist each other, that order and life should be the result. Without all the three, and all the three constituted in their present manner, and subject to their present laws, living things could not exist. If the earth had no atmosphere, or if the world had no ether, all must be inert and dead. Who constructed these three extraordinary complex pieces of machinery, the earth with its productions, the atmosphere, and the ether? Who fitted them into each other in many parts, and thus made it possible for them to work together? We conceive there can be but one answer: a most wise and good God.

CHAPTER XVIII.

RECAPITULATION.

1. It has been shown in the preceding chapters that a great number of quantities and laws appear to have been *selected* in the construction of the universe; and that by the adjustment to each other of the magnitudes and laws thus selected, the constitution of the world is what we find it, and is fitted for the support of vegetables and animals, in a manner in which it could not have been, if the properties and quantities of the elements had been different from what they are. We shall here recapitulate the principal of the laws and magnitudes to which this conclusion has been shown to apply.

1. The Length of the Year, which depends on the force of the attraction of the sun, and its distance from the earth.
2. The Length of the Day.
3. The Mass of the Earth, which depends on its magnitude and density.
4. The Magnitude of the Ocean.
5. The Magnitude of the Atmosphere.
6. The Law and Rate of the Conducting Power of the Earth.
7. The Law and Rate of the Radiating Power of the Earth.
8. The Law and Rate of the Expansion of Water by Heat.
9. The Law and Rate of the Expansion of Water by Cold, below 40 degrees.
10. The Law and Quantity of the Expansion of water in Freezing.
11. The Quantity of Latent Heat absorbed in Thawing.
12. The Quantity of Latent Heat absorbed in Evaporation.
13. The Law and Rate of Evaporation with regard to Heat.
14. The Law and Rate of the Expansion of Air by Heat.
15. The Quantity of Heat absorbed in the Expansion of Air.
16. The Law and Rate of the Passage of Aqueous Vapour through Air.
17. The Laws of Electricity; its relations to Air and Moisture.
18. The Fluidity, Density, and Elasticity, of the Air, by means of which its vibrations produce Sound.
19. The Fluidity, Density, and Elasticity of the Ether, by means of which its vibrations produce Light.

2. These are the *data*, the *elements*, as astronomers call the quantities which determine a planet's orbit, on which the mere *inorganic* part of the universe is constructed. To these, the constitution of the organic world is adapted in innumerable points, by laws of which we can trace the results, though we cannot analyze their machinery. Thus, the vital functions of vegetables have periods which correspond to the length of the year, and of the day; their vital powers have forces which correspond to the force of gravity; the sentient faculties of man are such that the vibrations of air, (within certain limits,) are perceived as sound, those of ether, as light. And while we are enumerating these correspondences, we perceive that there are thousands of others, and that we can only select a very small number of those where the relation happens to be most clearly made out or most easily explained.

Now, in the list of the mathematical *elements* of the universe which has just been given, why have we such laws and such quantities as there occur, and no other? For the most part, the data there enumerated are independent of each other, and might be altered separately, so far as the mechanical conditions of the case are concerned. Some of these data probably depend on each other. Thus the latent heat of aqueous vapour is perhaps connected with the difference of the rate of expansion of water and of steam. But all natural philosophers will, probably, agree, that there must be, in this list, a great number of things entirely without any mutual dependence, as the year and the day, the expansion of air and the expansion of steam. There are, therefore, it appears, a number of things which, in the structure of the world, might have been otherwise, and which are what they are in consequence of choice or of chance. We have already seen, in many of the cases separately, how unlike chance everything looks:—that substances, which might have existed any how, so far as they themselves are concerned, exist exactly in such a manner and measure as they should, to secure the welfare of other things:—that the laws are tempered and fitted together in the only way in which the world could have gone on, according to all that we can conceive of it. This must, therefore, be the work of choice; and if so, it cannot be doubted, of a most wise and benevolent Chooser.

3. The appearance of choice is still further illustrated by the variety as well as the number of the laws selected. The laws are unlike one another. Steam certainly expands at a very different *rate* from air by the application of heat, probably according to a different *law:* water expands in freezing, but mercury contracts: heat travels in a manner quite different through solids and fluids. Every separate substance has its own density, gravity, cohesion, elasticity, its relations to heat, to electricity, to magnetism; besides all its chemical affinities, which form an endless throng of laws, connecting every one substance in creation with every other, and

different for each pair any how taken. Nothing can look less like a world formed of atoms operating upon each other according to some universal and inevitable laws, than this does: if such a system of things be conceivable, it cannot be our system. We have, it may be, fifty simple substances in the world; each of which is invested with properties, both of chemical and mechanical action, altogether different from those of any other substance. Every portion, however minute, of any of these, possesses all the properties of the substance. Of each of these substances there is a certain unalterable quantity in the universe; when combined, their compounds exhibit new chemical affinities, new mechanical laws. Who gave these different laws to the different substances? who proportioned the quantity of each? But suppose this done. Suppose these substances in existence; in contact; in due proportion to each other. Is *this* a world, or at least our world? No more than the mine and the forest are the ship of war or the factory. These elements, with their constitution perfect, and their proportion suitable, are still a mere chaos. They must be put in their places. They must not be where their own properties would place them. They must be made to assume a particular arrangement, or we can have no regular and permanent course of nature. This arrangement must again have additional peculiarities, or we can have no organic portion of the world. The millions of millions of particles which the world contains, must be finished up in as complete a manner, and fitted into their places with as much nicety, as the most delicate wheel or spring in a piece of human machinery. What are the habits of thought to which it can appear possible that this could take place without design, intention, intelligence, purpose, knowledge?

In what has just been said, we have spoken only of the constitution of the inorganic part of the universe. The mechanism, if we may so call it, of vegetable and animal life, is so far beyond our comprehension, that though some of the same observations might be applied to it, we do not dwell upon the subject. We know that in these processes also, the mechanical and chemical properties of matter are necessary, but we know too that these alone will not account for the phenomena of life. There is something more than these. The lowest stage of vitality and irritability appears to carry us beyond mechanism, beyond affinity. All that has been said with regard to the exactness of the adjustments, the combination of various means, the tendency to continuance, to preservation, is applicable with additional force to the organic creation, so far as we can perceive the means employed. These, however, belong to a different province of the subject, and must be left to other hands.

BOOK II.

COSMICAL ARRANGEMENTS.

When we turn our attention to the larger portions of the universe, the sun, the planets, and the earth as one of them, the moon and other satellites, the fixed stars and other heavenly bodies;—the views which we obtain concerning their mutual relations, arrangement and movements, are called, as we have already stated, *cosmical* views. These views will, we conceive, afford us indications of the wisdom and care of the Power by which the objects which we thus consider, were created and are preserved: and we shall now proceed to point out some circumstances in which these attributes may be traced.

It has been observed by writers on Natural Theology, that the arguments for the being and perfections of the Creator, drawn from cosmical considerations, labour under some disadvantages when compared with the arguments founded on those provisions and adaptations which more immediately affect the well-being of organized creatures. The structure of the solar system has far less analogy with such machinery as we can construct and comprehend, than we find in the structure of the bodies of animals, or even in the causes of the weather. Moreover, we do not see the immediate bearing of cosmical arrangements on that end which we most readily acknowledge to be useful and desirable, the support and comfort of sentient natures. So that, from both causes, the impression of benevolent design in this case is less striking and pointed than that which results from the examination of some other parts of nature.

But in considering the universe, according to the view we have taken, as a collection of *laws*, astronomy, the science which teaches us the laws of the motions of the heavenly bodies, possesses some advantages, among the subjects from which we may seek to learn the character of the government of the world. For our knowledge of the laws of the motions of the planets and satellites is far more complete and exact, far more thorough and satisfactory, than the knowledge which we possess in any other department of Natural Philosophy. Our acquaintance with the laws of the solar system is such, that we can calculate the precise place and motion of most

of its parts at any period, past or future, however remote; and we can refer the changes which take place in these circumstances to their proximate cause, the attraction of one mass of matter to another, acting between all the parts of the universe.

If, therefore, we trace indications of the Divine care, either in the form of the laws which prevail among the heavenly bodies, or in the arbitrary quantities which such laws involve; (according to the distinction explained in the former part of this work ;) we may expect that our examples of such care, though they may be less numerous and obvious, will be more precise than they can be in other subjects, where the laws of facts are imperfectly known, and their causes entirely hid. We trust that this will be found to be the case with regard to some of the examples which we shall adduce.

CHAPTER I.

THE STRUCTURE OF THE SOLAR SYSTEM.

In the cosmical considerations which we have to offer, we shall suppose the general truths concerning the structure of the solar system and of the universe, which have been established by astronomers and mathematicians, to be known to the reader. It is not necessary to go into much detail on this subject. The five planets known to the ancients, Mercury, Venus, Mars, Jupiter, Saturn, revolve round the sun, at different distances, in orbits nearly circular, and nearly in one plane. Between Venus and Mars, our Earth, herself one of the planets, revolves in like manner. Beyond Saturn, Uranus has been discovered describing an orbit of the same kind; and between Mars and Jupiter, four smaller bodies perform their revolutions in orbits somewhat less regular than the rest. These planets are all nearly globular, and all revolve upon their axes. Some of them are accompanied by satellites, or attendant bodies which revolve about them; and these bodies also have their orbits nearly circular, and nearly in the same plane as the others. Saturn's ring is a solitary example, so far as we know, of such an appendage to a planet.

These circular motions of the planets round the sun, and of the satellites round their primary planets, are all kept going by the *attraction* of the respective central bodies, which restrains the corresponding revolving bodies from flying off. It is perhaps not very easy to make this operation clear to common apprehension. We cannot illustrate it by a comparision with any machine of human contrivance and fabrication: in such machines everything goes on by contact and

impulse: pressure, and force of all kinds, is exercised and transferred from one part to another, by means of a material connexion; by rods, ropes, fluids, gases. In the machinery of the universe there is, so far as we know, no material connexion between the parts which act on each other. In the solar system no part touches or drives another: all the bodies affect each other *at a distance*, as the magnet affects the needle. The production and regulation of such effects, if attempted by our mechanicians, would require great skill and nicety of adjustment; but our artists have not executed any examples of this sort of machinery, by reference to which we can illustrate the arrangements of the solar system.

Perhaps the following comparison may serve to explain the kind of adjustments of which we shall have to speak. If there be a wide shallow round basin of smooth marble, and if we take a smooth ball, as a billiard ball or a marble pellet, and throw it along the surface of the inside of the basin, the ball will generally make many revolutions round the inside of the bowl, gradually tending to the bottom in its motion. The gradual diminution of the motion, and consequent tendency of the ball to the bottom of the bowl, arises from the friction; and in order to make the motion correspond to that which takes place through the action of a central force, we must suppose this friction to be got rid of. In this case, the ball, once set a going, would run round the basin for ever, describing either a circle, or various kinds of ovals, according to the way in which it was originally thrown; whether quick or slow, and whether more or less obliquely along the surface.

Such a motion would be capable of the same kind of variety, and the same sort of adjustments, as the motion of a body revolving about a larger one by means of a central force. Perhaps the reader may understand what kind of adjustments these are, by supposing such a bowl and ball to be used for a game of skill. If the object of the players be to throw the pellet along the surface of the basin, so that after describing its curved path it shall pass through a small hole in a barrier at some distance from the starting point, it will easily be understood that some nicety in the regulation of the force and direction with which the ball is thrown will be necessary for success. In order to obtain a better image of the solar system, we must suppose the basin to be very large and the pellet very small. And it will easily be understood that as many pellets as there are planets might run round the bowl at the same time with different velocities. Such a contrivance might form a *planetarium* in which the mimic planets would be regulated by the laws of motion as the real planets are; instead of being carried by wires and wheels, as is done in such machines of the common construction: and in this planetarium the tendency of the planets to the sun is replaced by the tendency of the representative pellets to run down the slope of the bowl. We shall refer again to this basin, thus representing the solar system with its loose planetary balls.

CHAPTER II.

THE CIRCULAR ORBITS OF THE PLANETS ROUND THE SUN.

THE orbit which the earth describes round the sun is very nearly a circle: the sun is about one thirtieth nearer to us in winter, than in summer. This nearly circular form of the orbit, on a little conderation, will appear to be a remarkable circumstance.

Supposing the attraction of a planet towards the sun to exist, if the planet were put in motion in any part of the solar system, it would describe about the sun an orbit *of some kind;* it might be a long oval, or a shorter oval, or an exact circle. But if we suppose the result left to chance, the chances are infinitely against the last-mentioned case. There is but one circle; there are an infinite number of ovals. Any original impulse would give some oval, but only one particular impulse, determinate in velocity and direction, will give a circle. If we suppose the planet to be originally *projected,* it must be projected perpendicularly to its distance from the sun, and with a certain precise velocity, in order that the motion may be circular.

In the basin to which we have compared the solar system, the adjustment requisite to produce circular motion would require us to project our pellet so that after running half round the surface it should touch a point exactly at an equal distance from the centre, on the other side, passing neither too high nor too low. And the pellet, it may be observed, should be in size only one ten thousandth part of the distance from the centre, to make the dimensions correspond with the cast of the earth's orbit. If the mark were set up and hit, we should hardly attribute the result to chance.

The earth's orbit, however, is not exactly a circle. The mark is not precisely a single point, but is a space of the breadth of one thirtieth of the distance from the centre. Still this is much too near an agreement with the circle to be considered as the work of chance. The chances were great against the ball passing so nearly at the same distance, for there were twenty-nine equal spaces through which it might have gone, between the mark and the centre, and an indefinite number outside the mark.

But it is not the earth's orbit alone which is nearly a circle: the rest of the planets also approach very nearly to that form: Venus more nearly still than the earth: Jupiter, Saturn, and Uranus have a difference of about one tenth, between their greatest and least distances from the sun: Mars has his extreme distances in the proportion of five to six nearly; and Mercury in the proportion of two to three. The last-mentioned case is a considerable deviation, and two of the small planets which lie between Mars and Jupiter, namely

Juno and Pallas, exhibit an inequality somewhat greater still; but the smallness of these bodies, and other circumstances, make it probable that there may be particular causes for the exception in their case. The orbits of the satellites of the Earth, of Jupiter and of Saturn, are also nearly circular.

Taking the solar system altogether, the regularity of its structure is very remarkable. The diagram which represents the orbits of the planets might have consisted of a number of ovals, narrow and wide in all degrees, intersecting and interfering with each other in all directions. The diagram does consist, as all who have opened a book of astronomy know, of a set of figures which appear at first sight concentric circles, and which are very nearly so; no where approaching to any crossing or interfering, except in the case of the small planets, already noticed as irregular. No one, looking at this common diagram, can believe that the orbits were made to be so nearly circles by chance; any more than he can believe that a target, such as archers are accustomed to shoot at, was painted in concentric circles by the accidental dashes of a brush in the hands of a blind man.

The regularity, then, of the solar system excludes the notion of accident in the arrangement of the orbits of the planets. There must have been an express adjustment to produce this circular character of the orbits. The velocity and direction of the motion of each planet must have been subject to some original regulation; or, as it is often expressed, the projectile force must have been accommodated to the centripetal force. This once done, the motion of each planet, taken by itself, would go on for ever still retaining its circular character, by the laws of motion.

If some original cause adjusted the orbits of the planets to their circular form and regular arrangement, we can hardly avoid including in our conception of this cause, the intention and will of a Creating Power. We shall consider this argument more fully in a succeeding chapter; only observing here, that the presiding Intelligence, which has selected and combined the properties of the organic creation, so that they correspond so remarkably with the arbitrary quantities of the system of the universe, may readily be conceived also to have selected the arbitrary velocity and direction of each planet's motion, so that the adjustment should produce a close approximation to a circular motion.

We have argued here only from the *regularity* of the solar system; from the selection of the single symmetrical case and the rejection of all the unsymmetrical cases. But this subject may be considered in another point of view. The system thus selected is not only regular and symmetrical, but also it is, so far as we can judge, the only one which would answer the purpose of the earth, perhaps of the other planets, as the seat of animal and vegetable life. If the earth's orbit were more eccentric, as it is called, if for instance the

greatest and least distances were as three to one, the inequality of heat at two seasons of the year would be destructive to the existing species of living creatures. A circular, or nearly circular, orbit, is the only case in which we can have a course of seasons such as we have at present, the only case in which the climates of the northern and southern hemispheres are nearly the same; and what is more clearly important, the only case in which the character of the seasons would not vary from century to century. For if the eccentricity of the earth's orbit were considerable, the difference of heat at different seasons, arising from the different distances of the sun, would be combined with the difference, now the only considerable one, which depends on the position of the earth's axis. And as by the motion of the *perihelion*, or place of the nearest distance of the earth to the sun, this nearest distance would fall in different ages at different parts of the year, the whole distribution of heat through the year would thus be gradually subverted. The summer and winter of the *tropical* year, as we have it now, being combined with the heat and cold of the *anomalistic* year, a period of different length, the difference of the two seasons might sometimes be neutralized altogether, and at other times exaggerated by the accumulation of the inequalities, so as to be intolerable.

The circular form of the orbit therefore, which, from its unique character, appears to be chosen with *some* design, from its effects on the seasons appears to be chosen with this design, so apparent in other parts of creation, of securing the welfare of organic life, by a steadfast and regular order of the solar influence upon the planet.

CHAPTER III.

THE STABILITY OF THE SOLAR SYSTEM.

There is a consequence resulting from the actual structure of the solar system, which has been brought to light by the investigations of mathematicians concerning the cause and laws of its motions, and which has an important bearing on our argument. It appears that the arrangement which at present obtains is precisely that which is necessary to secure the *stability* of the system. This point we must endeavour to explain.

If each planet were to revolve round the sun without being affected by other planets, there would be a certain degree of regularity in its motion; and this regularity would continue for ever. But it ap-

pears, by the discovery of the law of universal gravitation, that the planets do not execute their movements in this insulated and independent manner. Each of them is acted on by the attraction of all the rest. The Earth is constantly drawn by Venus, by Mars, by Jupiter, bodies of various magnitudes, perpetually changing their distances and positions with regard to the earth; the Earth in return is perpetually drawing these bodies. What, in the course of time, will be the result of this mutual attraction?

All the planets are very small compared with the sun, and therefore the derangement which they produce in the motion of one of their number will be very small in the course of one revolution. But this gives us no security that the derangement may not become very large in the course of many revolutions. The cause acts perpetually, and it has the whole extent of time to work in. Is it not easily conceivable then that in the lapse of ages the derangements of the motions of the planets may accumulate, the orbits may change their form, their mutual distances may be much increased or much diminished? Is it not possible that these changes may go on without limit, and end in the complete subversion and ruin of the system?

If, for instance, the result of this mutual gravitation should be to increase considerably the eccentricity of the earth's orbit, that is to make it a longer and longer oval; or to make the moon approach perpetually nearer and nearer the earth every revolution; it is easy to see that in the one case our year would change its character, as we have noticed in the last section; in the other, our satellite might finally fall to the earth, which must of course bring about a dreadful catastrophe. If the positions of the planetary orbits, with respect to that of the earth, were to change much, the planets might sometimes come very near us, and thus exaggerate the effects of their attraction beyond calculable limits. Under such circumstances, we might have "years of unequal length, and seasons of capricious temperature, planets and moons of portentous size and aspect, glaring and disappearing at uncertain intervals;" tides like deluges, sweeping over whole continents; and, perhaps, the collision of two of the planets, and the consequent destruction of all organization on both of them.

Nor is it, on a common examination of the history of the solar system, at all clear that there is no tendency to indefinite derangement. The fact really is, that changes are taking place in the motions of the heavenly bodies, which have gone on progressively from the first dawn of science. The eccentricity of the earth's orbit has been diminishing from the earliest observations to our times. The moon has been moving quicker and quicker from the time of the first recorded eclipses, and is now in advance, by about four times her own breadth, of what her place would have been if it had not been affected by this acceleration. The obliquity of the ecliptic also

is in a state of diminution, and is now about two-fifths of a degree less than it was in the time of Aristotle. Will these changes go on without limit or reaction? If so, we tend by natural causes to a termination of the present system of things: If not, by what adjustment or combination are we secured from such a tendency? Is the system *stable*, and if so, what is the condition on which its stability depends?

To answer these questions is far from easy. The mechanical problem which they involve is no less than this:—Having given the directions and velocities with which about thirty bodies are moving at one time, to find their places and motions after any number of ages; each of the bodies, all the while, attracting all the others, and being attracted by them all.

It may readily be imagined that this is a problem of extreme complexity, when it is considered that every new *configuration* or arrangement of the bodies will give rise to a new amount of action on each; and every new action to a new configuration. Accordingly, the mathematical investigation of such questions as the above was too difficult to be attempted in the earlier periods of the progress of Physical Astronomy. Newton did not undertake to demonstrate either the stability or the instability of the system. The decision of this point required a great number of preparatory steps and simplifications, and such progress in the invention and improvement of mathematical methods, as occupied the best mathematicians of Europe for the greater part of last century. But, towards the end of that time, it was shown by Lagrange and Laplace that the arrangements of the solar system are stable: that in the long run, the orbits and motions remain unchanged; and that the changes in the orbits, which take place in shorter periods, never transgress certain very moderate limits. Each orbit undergoes deviations on this side and on that of its average state; but these deviations are never very great, and it finally recovers from them, so that the average is preserved. The planets produce perpetual perturbations in each other's motions, but these perturbations are not indefinitely progressive, they are periodical: they reach a *maximum* value and then diminish. The periods which this restoration requires are, for the most part, enormous; not less than thousands, and, in some instances, millions of years; and hence it is, that some of these apparent derangements have been going on in the same direction since the beginning of the history of the world. But the restoration is in the sequel as complete as the derangement; and in the mean time the disturbance never attains a sufficient amount seriously to alter the adaptations of the system.*

The same examination of the subject by which this is proved, points out also the conditions on which this stability depends. "I have succeeded in demonstrating," says Laplace, "that whatever be the

* Laplace Expos. du Syst. du Monde. p. 441.

masses of the planets, in consequence of the fact that they all move in the same direction, in orbits of small eccentricity, and slightly inclined to each other—their secular inequalities are periodical and included within narrow limits; so that the planetary system will only oscillate about a mean state, and will never deviate from it except by a very small quantity. The ellipses of the planets have been, and always will be, nearly circular. The ecliptic will never coincide with the equator, and the entire extent of the variation in its inclination cannot exceed three degrees."

There exists, therefore, it appears, in the solar system, a provision for the permanent regularity of its motions; and this provision is found in the fact that the orbits of the planets are nearly circular, and nearly in the same plane, and the motions all in the same direction, namely, from west to east.*

Now is it probable that the occurrence of these conditions of stability in the disposition of the solar system is the work of chance? Such a supposition appears to be quite inadmissible. Any one of the orbits might have had any eccentricity.† In that of Mercury, where it is much the greatest, it is only one-fifth. How came it to pass that the orbits were not more elongated? A little more or a little less velocity in their orignal motions would have made them so. They might have had any inclination to the ecliptic from *no* degrees to ninety degrees. Mercury, which again deviates most widely, is inclined $7\frac{3}{4}$ degrees, Venus $3\frac{3}{4}$, Saturn $2\frac{3}{4}$, Jupiter $1\frac{1}{2}$, Mars 2. How came it that their motions are thus contained within such a narrow strip of the sky? One, or any number of them, might have moved from east to west: none of them does so. And these circumstances, which appear to be, each in particular, requisite for the stability of the system and the smallness of its disturbances, are all found in combination. Does not this imply both clear purpose and profound skill?

* In this statement of Laplace, however, one remarkable provision for the stability of the system is not noticed. The planets Mercury and Mars, which have much the largest eccentricities among the old planets, are those of which the masses are much the smallest. The mass of Jupiter is more than 2000 times that of either of these planets. If the orbit of Jupiter were as eccentric as that of Mercury is, all the security for the stability of the system, which analysis has yet pointed out, would disappear. The earth and the smaller planets might in that case change their approximately circular orbits into very long ellipses, and thus might fall into the sun, or fly off into remote space.

It is further remarkable that in the newly discovered planets, of which the orbits are still more eccentric than that of Mercury, the masses are still smaller, so that the same provision is established in this case also. It does not appear that any mathematician has even attempted to point out a necessary connexion between the mass of a planet and the eccentricity of its orbit on any hypothesis. May we not then consider this combination of small masses with large eccentricities, so important to the purposes of the world, as a mark of provident care in the Creator?

† The *eccentricity* of a planet's orbit is measured by taking the proportion of the *difference* of the greatest and least distances from the sun, to the *sum* of the same distances. Mercury's greatest and least distances are as 2 and 3; his eccentricity therefore is one-fifth.

It is difficult to convey an adequate notion of the extreme complexity of the task thus executed. A number of bodies, all attracting each other, are to be projected in such a manner that their revolutions shall be permanent and stable, their mutual perturbations always small. If we return to the basin with its rolling balls, by which we before represented the solar system, we must complicate with new conditions the trial of skill which we supposed. The problem must now be to project at once seven such balls, all connected by strings which influence their movements, so that each may hit its respective mark. And we must further suppose, that the marks are to be hit after many thousand revolutions of the balls. No one will imagine that this could be done by accident.

In fact it is allowed by all those who have considered this subject, that such a coincidence of the existing state with the mechanical requisites of permanency cannot be accidental. Laplace has attempted to calculate the probability that it is not the result of accident. He takes into account, in addition to the motions which we have mentioned, the revolutions of the satellites about their primaries, and of the sun and planets about their axes: and he finds that there is a probability, far higher than that which we have for the greater part of undoubted historical events, that these appearances are not the effect of chance. "We ought, therefore," he says, "to believe, with at least the same confidence, that a primitive cause has directed the planetary motions."

The solar system is thus, by the confession of all sides, completely different from anything which we might anticipate from the casual operation of its known laws. The laws of motion are no less obeyed to the letter in the most irregular than in the most regular motions; no less in the varied circuit of the ball which flies round a tennis court, than in the going of a clock; no less in the fantastical jets and leaps which breakers make when they burst in a corner of a rocky shore, than in the steady swell of the open sea. The laws of motion alone will not produce the regularity which we admire in the motions of the heavenly bodies. There must be an original adjustment of the system on which these laws are to act; a selection of the arbitrary quantities which they are to involve; a primitive cause which shall dispose the elements in due relation to each other, in order that regular recurrence may accompany constant change; that perpetual motion may be combined with perpetual stability; that derangements which go on increasing for thousands or for millions of years may finally cure themselves; and that the same laws which lead the planets slightly aside from their paths, may narrowly limit their deviations, and bring them back from their almost imperceptible wanderings.

If a man does not deny that any possible peculiarity in the disposition of the planets with regard to the sun could afford evidence of a controlling and ordering purpose, it seems difficult to imagine how

he could look for evidence stronger than that which there actually is. Of all the innumerable possible cases of systems, governed by the existing laws of force and motion, that one is selected which alone produces such a steadfast periodicity, such a constant average of circumstances, as are, so far as we can conceive, necessary conditions for the existence of organic and sentient life. And this selection is so far from being an obvious or easily discovered means to this end, that the most profound and attentive consideration of the properties of space and number, with all the appliances and aids we can obtain, are barely sufficient to enable *us* to see that the end is thus secured, and that it can be secured in no other way. Surely the obvious impression which arises from this view of the subject is, that the solar system, with its adjustments, is the work of an Intelligence, who perceives, as is self-evident, those truths, to which we attain painfully and slowly, and after all imperfectly; who has employed in every part of creation refined contrivances, which we can only with effort understand; and who, in innumerable instances, exhibits to us what we should look upon as remarkable difficulties remarkably overcome, if it were not that, through the perfection of the provision, the trace of the difficulty is almost obliterated.

CHAPTER IV.

THE SUN IN THE CENTRE.

The next circumstance which we shall notice as indicative of design in the arrangement of the material portions of the solar system, is the position of the sun, the source of light and heat, in the centre of the system. This could hardly have occurred by anything which we can call chance. Let it be granted, that the law of gravitation is established, and that we have a large mass, with others much smaller in its comparative vicinity. The small bodies may then move round the larger, but this will do nothing towards making it a *sun* to them. Their motions might take place, the whole system remaining still utterly dark and cold, without day or summer. In order that we may have something more than this blank and dead assemblage of moving clods, the machine must be lighted up and warmed. Some of the advantages of placing the lighting and warming apparatus in the centre are obvious to us. It is in this way only that we could have those regular periodical returns of solar influence, which, as we have seen, are adapted to the constitution of the living creation. And we can easily conceive, that there may be other incongruities in a system with a travelling

sun, of which we can only conjecture the nature. No one probably will doubt that the existing system, with the sun in the centre, is better than any one of a different kind would be.

Now this lighting and warming by a central sun are something superadded to the mere mechanical arrangements of the universe. There is no apparent reason why the largest mass of gravitating matter should diffuse inexhaustible supplies of light and heat in all directions, while the other masses are merely passive, with respect to such influences. There is no obvious connexion between mass and luminousness, or temperature. No one, probably, will contend, that the materials of our system are necessarily luminous or hot. According to the conjectures of astronomers, the heat and light of the sun do not reside in its mass, but in a coating which lies on its surface. If such a coating were fixed there by the force of universal gravitation, how could we avoid having a similar coating on the surface of the earth, and of all the other globes of the system. If light consist in the vibrations of an ether, which we have mentioned as a probable opinion, why has the sun alone the power of exciting such vibrations? If light be the emission of material particles, why does the sun alone emit such particles? Similar questions may be asked, with regard to heat, whatever be the theory we adopt on that subject. Here then we appear to find marks of contrivance. The sun might become, we will suppose, the centre of the motions of the planets by mere mechanical causes: but what caused the centre of their motions to be also the source of those vivifying influences? Allowing that no interposition was requisite to regulate the revolutions of the system, yet observe what a peculiar arrangement in other respects was necessary, in order that these revolutions might produce days and seasons! The machine will move of itself, we may grant: but who constructed the machine, so that its movements might answer the purposes of life? How was the candle placed upon the candlestick? how was the fire deposited on the hearth, so that the comfort and well-being of the family might be secured? Did these two fall into their places by the casual operation of gravity? and, if not, is there not here a clear evidence of intelligent design, of arrangement with a benevolent end?

This argument is urged with great force by Newton himself. In his first letter to Bentley, he allows that matter might form itself into masses by the force of attraction. "And thus," says he, "might the sun and fixed stars be formed, supposing the matter were of a lucid nature. But how the matter should divide itself into two sorts; and that part of it which is fit to compose a shining body should fall down into one mass, and make a sun; and the rest, which is fit to compose an opake body, should coalesce, not into one great body, like the shining matter, but into many little ones; or if the sun at first were an opake body like the planets, or the planets

lucid bodies like the sun, how he alone should be changed into a shining body, whilst all they continue opake; or all they be changed into opake ones, while he continued unchanged: I do not think explicable by mere natural causes, but am forced to ascribe it to the counsel and contrivance of a voluntary Agent."

CHAPTER V.

THE SATELLITES.

1. A PERSON of ordinary feelings, who, on a fine moonlight night, sees our satellite pouring her mild radiance on field and town, path and moor, will probably not only be disposed to "bless the useful light," but also to believe that it was "ordained" for that purpose; —that the lesser light was made to rule the night as certainly as the greater light was made to rule the day.

Laplace, however, does not assent to this belief. He observes, that "some partisans of final causes have imagined that the moon was given to the earth to afford light during the night:" but he remarks that this cannot be so, for that we are often deprived at the same time of the light of the sun and the moon; and he points out how the moon might have been placed so as to be always "full."

That the light of the moon affords, *to a certain extent*, a supplement to the light of the sun, will hardly be denied. If we take man in a condition in which he uses artificial light scantily only, or not at all, there can be no doubt that the moonlight nights are for him a very important addition to the time of daylight. And as a small proportion only of the whole number of nights are without some portion of moonlight, the fact that sometimes both luminaries are invisible very little diminishes the value of this advantage. Why we have not more moonlight, either in duration or in quantity, is an inquiry which a philosopher could hardly be tempted to enter upon, by any success which has attended previous speculations of a similar nature. Why should not the moon be ten times as large as she is? Why should not the pupil of man's eye be ten times as large as it is, so as to receive more of the light which does arrive? We do not conceive that our inability to answer the latter question prevents our knowing that the eye was made for seeing: nor does our inability to answer the former, disturb our persuasion that the moon was made to give light upon the earth.

Laplace suggests that if the moon had been placed at a certain

distance beyond the earth, it would have revolved about the sun in the same time as the earth does, and would have always presented to us a full moon. For this purpose it must have been about four times as far from us as it really is; and would therefore, other things remaining unchanged, have only been *one sixteenth* as large to the eye as our present full moon. We shall not dwell on the discussion of this suggestion, for the reason just intimated. But we may observe that in such a system as Laplace proposes, it is not yet proved, we believe, that the arrangement would be stable under the influence of the disturbing forces. And we may add that such an arrangement, in which the motion of one body has a *co-ordinate* reference to two others, as the motion of the moon on this hypothesis would have to the sun and the earth, neither motion being subordinate to the other, is contrary to the whole known analogy of cosmical phenomena, and therefore has no claim to our notice as a subject of discussion.

2. In turning our consideration to the satellites of the other planets of our system, there is one fact which immediately arrests our attention;—the number of such attendant bodies appears to increase as we proceed to planets farther and farther from the sun. Such at least is the general rule. Mercury and Venus, the planets nearest the sun, have no such attendants: the Earth has one. Mars, indeed, who is still farther removed, has none; nor have the minor planets, Juno, Vesta, Ceres, Pallas; so that the rule is only approximately verified. But Jupiter, who is at five times the earth's distance, has four satellites; and Saturn, who is again at a distance nearly twice as great, has seven, besides that most extraordinary phenomenon his ring, which, for purposes of illumination, is equivalent to many thousand satellites. Of Uranus it is difficult to speak, for his great distance renders it almost impossible to observe the smaller circumstances of his condition. It does not appear at all probable that he has a ring, like Saturn; but he has at least five satellites which are visible to us, at the enormous distance of 900 millions of miles; and we believe that the astronomer will hardly deny that he may possibly have thousands of smaller ones circulating about him.

But leaving conjecture, and taking only the ascertained cases of Venus, the Earth, Jupiter, and Saturn, we conceive that a person of common understanding will be strongly impressed with the persuasion that the satellites are placed in the system with a view to compensate for the diminished light of the sun at greater distances. The smaller planets, Juno, Vesta, Ceres, and Pallas, differ from the rest in so many ways, and suggest so many conjectures of reasons for such differences, that we should almost expect to find them exceptions to such a rule. Mars is a more obvious exception. Some persons might conjecture from his case, that the arrangement itself, like other useful arrangements, has been brought about by some

wider law which we have not yet detected. But whether or not we entertain such a guess, (it can be nothing more,) we see in other parts of creation, so many examples of apparent exceptions to rules, which are afterwards found to be explained, or provided for by particular contrivances, that no one, familiar with such contemplations, will, by one anomaly, be driven from the persuasion that the end which the arrangements of the satellites seem suited to answer is really one of the ends of their creation.

CHAPTER VI.

THE STABILITY OF THE OCEAN.

What is meant by the stability of the ocean may perhaps be explained by means of the following illustration. If we suppose the whole globe of the Earth to be composed of water, a sphere of cork, immersed in any part of it, would come to the surface of the water, except it were placed exactly at the centre of the earth; and even if it were the slightest displacement of the cork sphere would end in its rising and floating. This would be the case whatever were the size of the cork sphere, and even if it were so large as to leave comparatively little room for the water; and the result would be nearly the same, if the cork sphere, when in its central position, had on its surface prominences which projected above the surface of the water. Now this brings us to the case in which we have a globe resembling our present earth, composed like it of water and of a solid centre, with islands and continents, but having these solid parts all made of cork. And it appears by the preceding reasoning, that in this case, if there were any disturbance either of the solid or fluid parts, the solid parts would rise from the centre of the watery sphere as far as they could: that is, all the water would run to one side and leave the land on the other. Such an ocean would be in *unstable* equilibrium.

Now a question naturally occurs, is the equilibrium of our present ocean of this unstable kind, or is it stable? The sea, after its most violent agitations, appears to return to its former state of repose; but may not some extraordinary cause produce in it some derangement which may go on increasing till the waters all rush one way, and thus drown the highest mountains? And if we are safe from this danger, what are the conditions by which we are so secured?

The illustration which we have employed obviously suggests the answer to this question; namely, that the equilibrium is unstable, so

long as the solid parts are of such a kind as to float in the fluid parts; and of course we should expect that the equilibrium will be stable whenever the contrary is the case, that is, when the solid parts of the earth are of greater specific gravity than the sea. A more systematic mathematical calculation has conducted Laplace to a demonstration of this result.

The mean specific gravity of the earth appears to be about *five* times that of water, so that the condition of the stability of the ocean is abundantly fulfilled. And the provision by which this stability is secured was put in force through the action of those causes, whatever they were, which made the density of the solid materials and central parts of the earth greater than the density of the incumbent fluid.

When we consider, however, the manner in which the wisdom of the Creator, even in those cases in which his care is most apparent, as in the structure of animals, works by means of intermediate causes and general laws, we shall not be ready to reject all belief of an end in such a case as this, merely because the means are mechanical agencies. Laplace says, "in virtue of gravity, the most dense of the strata of the earth are those nearest to the centre; and thus the mean density exceeds that of the waters which cover it: which suffices to secure the stability of the equilibrium of the seas, and to put a bridle upon the fury of the waves." This statement, if exact, would not prove that He who subjected the materials of the earth to the action of gravity did not *intend* to restrain the rage of the waters: but the statement is not true in fact. The lower strata, so far as man has yet examined, are very far from being constantly, or even generally, heavier than the superincumbent ones. And certainly solidification by no means implies a greater density than fluidity: the density of Jupiter is one fourth, that of Saturn less than one seventh, of that of the earth. If an ocean of water were poured into the cavities upon the surface of Saturn, its equilibrium would *not* be stable. It would leave its bed on one side of the globe; and the planet would finally be composed of one hemisphere of water and one of land. If the Earth had an ocean of a fluid six times as heavy as water, (quicksilver is thirteen times as heavy,) we should have, in like manner, a dry and a fluid hemisphere. Our inland rivers would probably never be able to reach the shores, but would be dried up on their way, like those which run in torrid deserts: perhaps the evaporation from the ocean would never reach the inland mountains, and we should have no rivers at all. Without attempting to imagine the details of such a condition, it is easy to see, that to secure the existence of a different one is an end which is in harmony with all that we see of the preserving care displayed in the rest of creation.*

* The stability of the axis of rotation about which the earth revolves has sometimes been adduced as an instance of preservative care. This stability, however,

CHAPTER VII.

THE NEBULAR HYPOTHESIS.

We have referred to Laplace, as a profound mathematician, who has strongly expressed the opinion, that the arrangement by which the stability of the solar system is secured is not the result of chance; that "*a primitive cause* has directed the planetary motions." This author, however, having arrived, as we have done, at this conviction, does not draw from it the conclusion which has appeared to us so irresistible, that "the admirable arrangement of the solar system cannot but be the work of an intelligent and most powerful being." He quotes these expressions, which are those of Newton, and points at them as instances where that great philosopher had deviated from the method of true philosophy. He himself proposes an hypothesis concerning the nature of the *primitive cause* of which he conceives the existence to be thus probable: and this hypothesis, on account of the facts which it attempts to combine, the view of the universe which it presents, and the eminence of the person by whom it is propounded, deserves our notice.

1. Laplace conjectures that in the original condition of the solar system, the sun revolved upon his axis, surrounded by an atmosphere which, in virtue of an excessive heat, extended far beyond the orbits of all the planets, the planets as yet having no existence. The heat gradually diminished, and as the solar atmosphere contracted by cooling, the rapidity of its rotation increased by the laws of rotatory motion, and an exterior zone of vapour was detatched from the rest, the central attraction being no longer able to overcome the increased centrifugal force. This zone of vapour might in some cases retain its form, as we see it in Saturn's ring; but more usually the ring of vapour would break into several masses, and these would generally coalesce into one mass, which would revolve about the sun. Such portions of the solar atmosphere, abandoned successively at different distances, would form "planets in the state of vapour." These planets, it appears from mechanical considerations, would have each its rotatory motion, and as the cooling of the vapour still went on, would each produce a planet, which might have satellites and rings, formed from the planet in the same manner as the planets were formed from the atmosphere of the sun.

would follow necessarily, if the earth, or its superficial parts, were originally fluid; and that they were so is an opinion widely received, both among astronomers and geologists. The original fluidity of the earth is probably a circumstance depending upon the general scheme of creation; and cannot with propriety be considered with reference to one particular result. We shall therefore omit any further consideration of this argument.

It may easily be conceived that all the primary motions of a system so produced would be nearly circular, nearly in the plane of the original equator of the solar rotation, and in the direction of that rotation. Reasons are offered also to show that the motions of the satellites thus produced and the motions of rotation of the planets must be in the same direction. And thus it is held that the hypothesis accounts for the most remarkable circumstances in the structure of the solar system: namely, the motions of the planets in the same direction, and almost in the same plane; the motions of the satellites in the same direction as those of the planets; the motions of rotation of these different bodies still in the same direction as the other motions, and in planes not much different; the small eccentricity of the orbits of the planets, upon which condition, along with some of the preceding ones, the stability of the system depends; and the position of the source of light and heat in the centre of the system.

It is not necessary for the purpose, nor suitable to the plan of the present treatise, to examine, on physical grounds, the probability of the above hypothesis. It is proposed by its author, with great diffidence, as a conjecture only. We might, therefore, very reasonably put off all discussion of the bearings of this opinion upon our views of the government of the world, till the opinion itself should have assumed a less indistinct and precarious form. It can be no charge against our doctrines, that there is a difficulty in reconciling with them arbitrary guesses, and half-formed theories. We shall, however, make a few observations upon this *nebular hypothesis*, as it may be termed.

2. If we grant, for a moment, the hypothesis, it by no means proves that the solar system was formed without the intervention of intelligence and design. It only transfers our view of the skill exercised, and the means employed, to another part of the work. For, how came the sun and its atmosphere to have such materials, such motions, such a constitution, that these consequences followed from their primordial condition? How came the parent vapour thus to be capable of coherence, separation, contraction, solidification? How came the laws of its motion, attraction, repulsion, condensation, to be so fixed, as to lead to a beautiful and harmonious system in the end? How came it to be neither too fluid nor too tenacious, to contract neither too quickly nor too slowly, for the successive formation of the several planetary bodies? How came that substance, which at one time was a luminous vapour, to be at a subsequent period, solids and fluids of many various kinds? What but design and intelligence prepared and tempered this previously existing element, so that it should by its natural changes produce such an orderly system?

And if in this way we suppose a planet to be produced, what sort of a body would it be?—something, it may be presumed, re-

sembling a large meteoric stone. How comes this mass to be covered with motion and organization, with life and happiness? What primitive cause stocked it with plants and animals, and produced all the wonderful and subtle contrivances which we find in their structure, all the wide and profound mutual dependencies which we trace in their economy? Was man, with his thought and feeling, his powers and hopes, his will and conscience, also produced as an ultimate result of the condensation of the solar atmosphere? Except we allow a prior purpose and intelligence presiding over this material "primitive cause," how irreconcilable is it with the evidence which crowds in upon us from every side!

3. In the next place, we may observe concerning this hypothesis, that it carries us back to the beginning of the present system of things; but that it is impossible for our reason to stop at the point thus presented to it. The sun, the earth, the planets, the moons were brought into their present order out of a previous state, and, as is supposed in the theory, by the natural operation of laws. But how came that previous state to exist? We are compelled to suppose that it, in like manner, was educed from a still prior state of things; and this, again, must have been the result of a condition prior still. Nor is it possible for us to find, in the tenets of the nebular hypothesis, any resting-place or satisfaction for the mind. The same reasoning faculty, which seeks for the origin of the present system of things, and is capable of assenting to, or dissenting from the hypothesis propounded by Laplace as an answer to this inquiry, is necessarily led to seek, in the same manner, for the origin of any previous system of things, out of which the present may appear to have grown: and must pursue this train of inquiries unremittingly, so long as the answer which it receives describes a mere assemblage of matter and motion; since it would be to contradict the laws of matter and the nature of motion, to suppose such an assemblage to be the *first* condition.

The reflection just stated, may be illustrated by the further consideration of the Nebular Hypothesis. This opinion refers us, for the origin of the solar system, to a sun surrounded with an atmosphere of enormously elevated temperature, revolving and cooling. But as we ascend to a still earlier period, what state of things are we to suppose?—a still higher temperature, a still more diffused atmosphere. Laplace conceives that, in its primitive state, the sun consisted in a diffused luminosity so as to resemble those nebulæ among the fixed stars, which are seen by the aid of the telescope, and which exhibit a nucleus, more or less brilliant, surrounded by a cloudy brightness. "This anterior state was itself preceded by other states, in which the nebulous matter was more and more diffuse, the nucleus being less and less luminous. We arrive," Laplace says, "in this manner, at a nebulosity so diffuse, that its existence could scarcely be suspected."

"Such is," he adds, "in fact, the first state of the nebulæ which Herschel carefully observed by means of his powerful telescopes. He traced the progress of condensation, not indeed on one nebula, for this progress can only become perceptible to us in the course of centuries; but in the assemblage of nebulæ; much in the same manner as in a large forest we may trace the growth of trees among the examples of different ages which stand side by side. He saw in the first place the nebulous matter dispersed in patches, in the different parts of the sky. He saw in some of these patches this matter feebly condensed round one or more faint nuclei. In other nebulæ, these nuclei were brighter in proportion to the surrounding nebulosity; when by a further condensation the atmosphere of each nucleus becomes separate from the others, the result is multiple nebulous stars, formed by brilliant nuclei very near each other, and each surrounded by an atmosphere: sometimes the nebulous matter condensing in a uniform manner has produced nebulous systems which are called *planetary*. Finally, a still greater degree of condensation transforms all these nebulous systems into stars. The nebulæ, classed according to this philosophical view, indicate with extreme probability their future transformation into stars, and the anterior nebulous condition of the stars which now exist."

It appears then that the highest point to which this series of conjectures can conduct us, is "an extremely diffused nebulosity," attended, we may suppose, by a far higher degree of heat, than that which, at a later period of the hypothetical process, keeps all the materials of our earth and planets in a state of vapour. Now is it not impossible to avoid asking, whence was this light, this heat, this diffusion? How came the laws which such a state implies, to be already in existence? Whether light and heat produce their effects by means of fluid vehicles or otherwise, they have complex and varied laws which indicate the existence of some subtle machinery for their action. When and how was this machinery constructed? Whence too that enormous expansive power which the nebulous matter is supposed to possess? And if, as would seem to be supposed in this doctrine, all the material ingredients of the earth existed in this diffuse nebulosity, either in the state of vapour, or in some state of still greater expansion, whence were they and their properties? how came there to be of each simple substance which now enters into the composition of the universe, just so much and no more? Do we not, far more than ever, require an origin of this origin? an explanation of this explanation? Whatever may be the merits of the opinion as a physical hypothesis, with which we do not here meddle, can it for a moment prevent our looking beyond the hypothesis, to a First Cause, an Intelligent Author, an origin proceeding from free volition, not from material necessity?

But again: let us ascend to the highest point of the hypothetical progression: let us suppose the nebulosity diffused throughout all

space, so that its course of running into patches is not yet begun. How are we to suppose it distributed? Is it equably diffused in every part? clearly not; for if it were, what should cause it to gather into masses, so various in size, form and arrangement? The separation of the nebulous matter into distinct nebulæ implies necessarily some original inequality of distribution; some determining circumstances in its primitive condition. Whence were these circumstances? this inequality? we are still compelled to seek some ulterior agency and power.

Why must the primeval condition be one of change at all? Why should not the nebulous matter be equably diffused throughout space, and continue for ever in its state of equable diffusion, as it must do, from the absence of all cause to determine the time and manner of its separation? why should this nebulous matter grow cooler and cooler? why should it not retain for ever the same degree of heat, whatever heat be? If heat be a fluid, if to cool be to part with this fluid, as many philosophers suppose, what becomes of the fluid heat of the nebulous matter, as the matter cools down? Into what unoccupied region does it find its way?

Innumerable questions of the same kind might be asked, and the conclusion to be drawn is, that every new physical theory which we include in our view of the universe, involves us in new difficulties and perplexities, if we try to erect it into an ultimate and final account of the existence and arrangement of the world in which we live. With the evidence of such theories, considered as scientific generalizations of ascertained facts, with their claims to a place in our natural philosophy, we have here nothing to do. But if they are put forwards as a disclosure of the ultimate cause of that which occurs, and as superseding the necessity of looking further or higher; if they claim a place in our Natural Theology, as well as our Natural Philosophy; we conceive that their pretensions will not bear a moment's examination.

Leaving then to other persons and to future ages to decide upon the scientific merits of the nebular hypothesis, we conceive that the final fate of this opinion cannot, in sound reason, affect at all the view which we have been endeavouring to illustrate;—the view of the universe as the work of a wise and good Creator. Let it be supposed that the point to which this hypothesis leads us, is the ultimate point of physical science: that the farthest glimpse we can obtain of the material universe by our natural faculties, shows it to us occupied by a boundless abyss of luminous matter: still we ask, how space came to be thus occupied, how matter came to be thus luminous? If we establish by physical proofs, that the first fact which can be traced in the history of the world, is that "there was light:" we shall still be led, even by our natural reason, to suppose that before this could occur, "God said, let there be light."

CHAPTER VIII.

THE EXISTENCE OF A RESISTING MEDIUM IN THE SOLAR SYSTEM.

THE question of a *plenum* and a *vacuum* was formerly much debated among those who speculated concerning the constitution of the universe; that is, they disputed whether the celestial and terrestrial spaces are absolutely full, each portion being occupied by some matter or other; or whether there are, between and among the material parts of the world, empty spaces free from all matter, however rare. This question was often treated by means of abstract conceptions and *à priori* reasonings; and was sometimes considered as one in which the result of the struggle between rival systems of philosophy, the Cartesian and Newtonian for instance, was involved. It was conceived by some that the Newtonian doctrine of the motions of the heavenly bodies, according to mechanical laws, required that the space in which they moved should be, absolutely and metaphysically speaking, a vacuum.

This, however, is not necessary to the truth of the Newtonian doctrines, and does not appear to have been intended to be asserted by Newton himself. Undoubtedly, according to his theory, the motions of the heavenly bodies were calculated *on the supposition* that they do move in a space void of any resisting fluid; and the comparison of the places so calculated with the places actually observed, (continued for a long course of years, and tried in innumerable cases,) did not show any difference which implied the existence of a resisting fluid. The Newtonian, therefore, was justified in asserting that *either* there was no such fluid, *or* that it was so thin and rarefied, that no phenomenon yet examined by astronomers was capable of betraying its effects.

This was all that the Newtonian needed or ought to maintain: for his philosophy, founded altogether upon observation, had nothing to do with abstract possibilities and metaphysical necessities. And in the same manner in which observation and calculation thus showed that there could be none but a very rare medium pervading the solar system, it was left open to observation and calculation to prove that there was such a medium, if any facts could be discovered which offered suitable evidence.

Within the last few years, facts have been observed which show, in the opinion of some of the best mathematicians of Europe, that such a very rare medium does really occupy the spaces in which the planets move; and it may be proper and interesting to consider the bearing of this opinion upon the views and arguments which we have had here to present.

1. Reasons might be offered, founded on the universal diffusion of

light and on other grounds, for believing that the planetary spaces cannot be entirely free from matter of some kind; and wherever matter is, we should expect resistance. But the facts which have thus led astronomers to the conviction that such a resisting medium really exists, are certain circumstances occurring in the motion of a body revolving round the sun, which is now usually called *Encke's comet.* This body revolves in a very eccentric or oblong orbit, its greatest or aphelion distance from the sun, and its nearest or perihelion distance, being in the proportion of more than ten to one. In this respect it agrees with other comets; but its time of revolution about the sun is much less than that of the comets which have excited most notice; for while they appear only at long intervals of years, the body of which we are now speaking returns to its perihelion every 1208 days, or in about three years and one-third. Another observable circumstance in this singular body, is its extreme apparent tenuity: it appears as a loose indefinitely formed speck of vapour, through which the stars are visible with no perceptible diminution of their brightness. This body was first seen by Mechain and Messier, in 1786,* but they obtained only two observations, whereas three, at least, are requisite to determine the path of a heavenly body. Miss Herschel discovered it again in 1795, and it was observed by several European astronomers. In 1805 it was again seen, and again in 1819. Hitherto it was supposed that the four comets thus observed were all different; Encke, however, showed that the observations could only be explained by considering them as returns of the same revolving body; and by doing this, well merited that his name should be associated with the subject of his discovery. The return of this body in 1822, was calculated beforehand, and observed in New South Wales, the comet being then in the southern part of the heavens; but on comparing the calculated and the observed places, Encke concluded that the observations could not be exactly explained, without supposing a resisting medium. This comet was again generally observed in Europe in 1825 and 1828, and the circumstances of the last appearance were particularly favourable for determining the absolute amount of the retardation arising from the medium, which the other observations had left undetermined.

The effect of this retarding influence is, as might be supposed from what has already been said, extremely slight; and would probably not have been perceptible at all, but for the loose texture and small quantity of matter of the revolving body. It will easily be conceived that a body which has perhaps no more solidity or coherence than a cloud of dust, or a wreath of smoke, will have less force to make its way through a fluid medium, however thin, than a more dense and compact body would have. In atmospheric air much

* Airy on Encke's Comet, p. 1. note.

rarefied, a bullet might proceed for miles without losing any of its velocity, while such a loose mass as the comet is supposed to be would lose its projectile motion in the space of a few yards. This consideration will account for the circumstance, that the existence of such a medium has been detected by observing the motions of Encke's comet, though the motions of the heavenly bodies previously observed showed no trace of such an impediment.

It will perhaps appear remarkable that a body so light and loose as we have described this comet to be, should revolve about the sun by laws as fixed and certain as those which regulate the motions of those great and solid masses, the Earth and Jupiter. It is however certain from observation, that this comet is acted upon by exactly the same force of solar attraction, as the other bodies of the system; and not only so, but that it also experiences the same kind of disturbing force from the action of the other planets, which they exercise upon each other. The effect of all these causes has been calculated with great care and labour; and the result has been an agreement with observation sufficiently close to show that these causes really act, but at the same time a *residual phenomenon* (as Sir J. Herschel expresses it) has come to light: and from this has been collected the inference of a resisting medium.

This medium produces a very small effect upon the motion of the comet, as will easily be supposed from what has been said. By Encke's calculation, it appears that the effect of the resistance, supposing the comet to move in the earth's orbit, would be about 1-850th of the sun's force on the body. The effect of such a resistance may appear, at first sight, paradoxical; it wou'd be to make the comet *move* more slowly, but *perform its revolutions* more quickly. This, however, will perhaps be understood if it be considered that by *moving* more slowly the comet will be more rapidly *drawn* towards the centre, and that in this way a revolution will be described by a shorter path than it was before. It appears, that in getting round the sun, the comet gains more in this way than it loses by the diminution of its velocity. The case is much like that of a stone thrown in the air; the stone moves more slowly than it would do if there were no air; but yet it comes to the earth *sooner* than it would do on that supposition.

It appears that the effect of the resistance of the ethereal medium, from the first discovery of the comet up to the present time, has been to diminish the time of revolution by about two days: and the comet is ten days in advance of the place which it would have reached, if there had been no resistance.

2. The same medium which is thus shown to produce an effect upon Encke's comet, must also act upon the planets which move through the same spaces. The effect upon the planets, however, must be very much smaller than the effect upon the comet, in consequence of their greater quantity of matter.

It is not easy to assign any probable value, or even any certain limit, to the effect of the resisting medium upon the planets. We are entirely ignorant of the comparative mass of the comet, and of any of the planets; and hence, cannot make any calculation founded on such a comparison. Newton has endeavoured to show how small the resistance of the medium must be, if it exist.* The result of his calculation is, that if we take the density of the medium to be that which our air will have at 200 miles from the earth's surface, supposing the law of diminution of density to go on unaltered, and if we suppose Jupiter to move in such a medium, he would in a million years lose less than a millionth part of his velocity. If a planet, revolving about the sun, were to lose any portion of its velocity, by the effect of resistance, it would be drawn proportionally nearer the sun, the tendency towards the centre being no longer sufficiently counteracted by that centrifugal force which arises from the body's velocity. And if the resistance were to continue to act, the body would be drawn perpetually nearer and nearer to the centre, and would describe its revolutions quicker and quicker, till at last it would reach the central body, and the system would cease to be a system.

This result is true, however small be the velocity lost by resistance; the only difference being, that when the resistance is small, the time requisite to extinguish the whole motion will be proportionally longer. In all cases the times which come under our consideration in problems of this kind, are enormous to common apprehension. Thus Encke's comet, according to the results of the observations already made, will lose, in ten revolutions, or thirty-three years, less than 1-1000th of its velocity: and if this law were to continue, the velocity would not be reduced to one-half its present value in less than seven thousand revolutions or twenty-three thousand years. If Jupiter were to lose one-millionth of his velocity in a million years, (which, as has been seen, is far more than can be considered in any way probable,) he would require seventy millions of years to lose 1-1000th of the velocity; and a period seven hundred times as long to reduce the velocity to one-half. These are periods of time which quite overwhelm the imagination; and it is not pretended that the calculations are made with any pretensions to accuracy. But at the same time it is beyond doubt that though the intervals of time thus assigned to these changes are highly vague and uncertain, the changes themselves must, sooner or later, take place, in consequence of the existence of the resisting medium. Since there is such a retarding force perpetually acting, however slight it be, it must in the end destroy all the celestial motions. It may be millions of millions of years before the earth's retardation may perceptibly affect the apparent motion of the sun; but still the day will come (if the same

* Principia, b. iii. prop. x.

Providence which formed the system, should permit it to continue so long) when this cause will entirely change the length of our year and the course of our seasons, and finally stop the earth's motion round the sun altogether. The smallness of the resistance, however small we choose to suppose it, does not allow us to escape this certainty. There is a resisting medium; and, therefore, the movements of the solar system cannot go on for ever. The moment such a fluid is ascertained to exist, the eternity of the movements of the planets becomes as impossible as a perpetual motion on the earth.

3. The vast periods which are brought under our consideration in tracing the effects of the resisting medium, harmonize with all that we learn of the constitution of the universe from other sources. Millions, and millions of millions of years are expressions that at first sight appear fitted only to overwhelm and confound all our powers of thought; and such numbers are no doubt beyond the limits of anything which we distinctly conceive. But our powers of conception are suited rather to the wants and uses of common life, than to a complete survey of the universe. It is in no way unlikely that the whole duration of the solar system should be a period immeasurably great in our eyes, though demonstrably finite. Such enormous numbers have been brought under our notice by all the advances we have made in our knowledge of nature. The smallness of the objects detected by the microscope and of their parts;—the multitude of the stars which the best telescopes of modern times have discovered in the sky;—the duration assigned to the globe of the earth by geological investigation;—all these results require for their probable expression, numbers, which so far as we see, are on the same gigantic scale as the number of years in which the solar system will become entirely deranged. Such calculations depend in some degree on our relation to the vast aggregate of the works of our Creator; and no person who is accustomed to meditate on these subjects will be surprised that the numbers which such an occasion requires should oppress our comprehension. No one who has dwelt on the thought of a universal Creator and Preserver, will be surprised to find the conviction forced upon the mind by every new train of speculation, that viewed in reference to Him, our space is a point, our time a moment, our millions a handful, our permanence a quick decay.

Our knowledge of the vast periods, both geological and astronomical, of which we have spoken, is most slight. It is in fact little more than that such periods exist; that the surface of the earth has, at wide intervals of time, undergone great changes in the disposition of land and water, and in the forms of animal life; and that the motions of the heavenly bodies round the sun are affected, though with inconceivable slowness, by a force which must end by deranging them altogether. It would therefore be rash to endeavour to establish any analogy between the periods thus disclosed: but we may observe that they *agree* in this, that they reduce all things to the general

rule of *finite duration.* As all the geological states of which we find evidence in the present state of the earth, have had their termination, as also the astronomical conditions under which the revolutions of the earth itself proceed, involve the necessity of a future cessation of these revolutions.

The contemplative person may well be struck by this universal law of the creation. We are in the habit sometimes of contrasting the transient destiny of man with the permanence of the forests, the mountains, the ocean,—with the unwearied circuit of the sun. But this contrast is a delusion of our own imagination: the difference is after all but one of degree. The forest tree endures for its centuries and then decays; the mountains crumble and change, and perhaps subside in some convulsion of nature; the sea retires, and the shore ceases to resound with the "everlasting" voice of the ocean: such reflections have already crowded upon the mind of the geologist; and it now appears that the courses of the heavens themselves are not exempt from the universal law of decay; that not only the rocks and the mountains, but the sun and the moon have the sentence "to end" stamped upon their foreheads. They enjoy no privilege beyond man except a longer respite. The ephemeron perishes in an hour; man endures for his threescore years and ten; an empire, a nation, numbers its centuries, it may be its thousands of years; the continents and islands which its dominion includes have perhaps their date, as those which preceded them have had; and the very revolutions of the sky by which centuries are numbered will at last languish and stand still.

To dwell on the moral and religious reflections suggested by this train of thought is not to our present purpose; but we may observe that it introduces a *homogeneity*, so to speak, into the government of the universe. Perpetual change, perpetual progression, increase and diminution, appear to be the rules of the material world, and to prevail without exception. The smaller portions of matter which we have near us, and the larger, which appear as luminaries at a vast distance, different as they are in our mode of conceiving them, obey the same laws of motion; and these laws produce the same results; in both cases motion is perpetually destroyed, except it be repaired by some living power; in both cases the relative rest of the parts of a material system is the conclusion to which its motion tends.

4. It may perhaps appear to some, that this acknowledgment of the tendency of the system to derangement through the action of a resisting medium is inconsistent with the argument which we have drawn in a previous chapter, from the provisions for its stability. In reality, however, the two views are in perfect agreement, so far as our purpose is concerned. The main point which we had to urge, in the consideration of the stability of the system, was, not that it is constructed to last for ever, but that while it lasts, the deviations from its mean condition are very small. It is this property which fits the

world for its uses. To maintain either the past or the future eternity of the world, does not appear consistent with physical principles, as it certainly does not fall in with the convictions of the religious man, in whatever way obtained. We conceive that this state of things has had a beginning; we conceive that it will have an end. But in the mean time we find it fitted, by a number of remarkable arrangements, to be the habitation of living creatures. The conditions which secure the stability, and the smallness of the perturbations of the system, are among these provisions. If the eccentricity of the orbit of Venus, or of Jupiter, were much greater than it is, not only might some of the planets, at the close of ages, fall into the sun or fly off into infinite space, but also, in the intermediate time, the earth's orbit might become much more eccentric; the course of the seasons and the average of temperature might vary from what they now are, so as to injure or destroy the whole organic creation. By certain original arrangements these destructive oscillations are prevented. So long as the bodies continue to revolve, their orbits will not be much different from what they now are. And this result is not affected by the action of the resisting medium. Such a medium cannot increase the small eccentricities of the orbits. The range of the periodical oscillations of heat and cold will not be extended by the mechanical effect of the medium, nor would be, even if its density were incomparably greater than it is. The resisting medium therefore does not at all counteract that which is most important in the provision for the permanency of the solar system. If the stability of the system had not been secured by the adjustments which we described in a former chapter, the course of the seasons might have been disturbed to an injurious or even destructive extent in the course of a few centuries, or even within the limits of one generation; by the effect of the resisting medium, the order of nature remains unchanged for a period, compared with which the known duration of the human race is insignificant.

But, it may be objected, the effect of the medium must be ultimately to affect the duration of the earth's revolution round the sun, and thus to derange those adaptations which depend on the length of the year. And, without question, if we permit ourselves to look forwards to that inconceivably distant period at which the effect of the medium will become sensible, this must be allowed to be true, as has been already stated. Millions, and probably millions of millions, of years express inadequately the distance of time at which this cause would produce a serious effect. That the machine of the universe is so constructed that it may answer its purposes for such a period, is surely sufficient proof of the skill of its workmanship, and of the reality of its purpose: and those persons, probably, who are best convinced that it is the work of a wise and good Creator, will be least disposed to consider

the system as imperfect, because in its present condition it is not fitted for eternity.

5. The doctrine of a Resisting Medium leads us towards a point which the Nebular Hypothesis assumes;—a *beginning* of the present order of things. There must have been a commencement of the motions now going on in the solar system. Since these motions, when once begun, would be deranged and destroyed in a period which, however large, is yet finite, it is obvious we cannot carry their origin indefinitely backwards in the range of past duration. There is a period in which these revolutions, whenever they had begun, would have brought the revolving bodies into contact with the central mass; and this period has in our system not yet elapsed. The watch is still going, and therefore it must have been wound up within a limited time.

The solar system, at this its beginning, must have been arranged and put in motion by some cause. If we suppose this cause to operate by means of the configurations and the properties of previously existing matter, these configurations must have resulted from some still previous cause, these properties must have produced some previous effects. We are thus led to a condition still earlier than the assumed beginning;—to an origin of the original state of the universe; and in this manner we are carried perpetually further and further back, through a labyrinth of mechanical causation, without any possibility of finding anything in which the mind can acquiesce or rest, till we admit "a First Cause which is not mechanical."

Thus the argument which was before urged against those in particular, who put forwards the Nebular Hypothesis in opposition to the admission of an Intelligent Creator, offers itself again, as cogent in itself, when we adopt the opinion of a resisting medium, for which the physical proofs have been found to be so strong. The argument is indeed forced upon our minds, whatever view we take of the past history of the universe. Some have endeavoured to evade its force by maintaining that the world as it now exists has existed from eternity. They assert that the present order of things, or an order of things in some way resembling the present, produced by the same causes, governed by the same laws, has prevailed through an infinite succession of past ages. We shall not dwell upon any objections to this tenet which might be drawn from our own conceptions, or from what may be called metaphysical sources. Nor shall we refer to the various considerations which history, geology, and astronomical records supply, and which tend to show, not only that the past duration of the present course of things is finite, but that it is short, compared with such periods as we have had to speak of. But we may observe, that the doctrine of a resisting medium once established, makes this imagination untenable; compels us to go back to the origin, not only of the present

course of the world, not only of the earth, but of the solar system itself; and thus sets us forth upon that path of research into the series of past causation, where we obtain no answer of which the meaning corresponds to our questions, till we rest in the conclusion of a most provident and most powerful Creating Intelligence.

It is related of Epicurus that when a boy, reading with his preceptor these verses of Hesiod,

> Ητοι μεν πρωτιστα Χαος γενετ', αυταρ επειτα
> Γαι' ευρυστερνος παντων εδος ασφαλες αιει
> Αθανατων,

> Eldest of beings, Chaos first arose,
> Thence Earth wide stretched, the steadfast seat of all
> The Immortals,

the young scholar first betrayed his inquisitive genius by asking "And chaos whence?" when in his riper years he had persuaded himself that this question was sufficiently answered by saying that chaos arose from the concourse of atoms, it is strange that the same inquisitive spirit did not again suggest the question "and atoms whence?" And it is clear that however often the question "whence?" had been answered, it would still start up as at first. Nor could it suffice as an answer to say, that earth, chaos, atoms, were portions of a series of changes which went back to eternity. The preceptor of Epicurus informed him, that to be satisfied on the subject of his inquiry, he must have recourse to the philosophers. If the young speculator had been told that chaos (if chaos indeed preceded the present order) was produced by an Eternal Being, in whom resided purpose and will, he would have received a suggestion which, duly matured by subsequent contemplation, might have led him to a philosophy far more satisfactory than the material scheme can ever be, to one who looks, either abroad into the universe, or within into his own bosom.

CHAPTER IX.

MECHANICAL LAWS.

In the preceding observations we have supposed the laws, by which different kinds of matter act and are acted upon, to be already in existence; and have endeavoured to point out evidences of design and adaptation, displayed in the selection and arrange-

ment of these materials of the universe. These materials are, it has appeared, supplied in such measures and disposed in such forms, that by means of their properties and laws the business of the world goes on harmoniously and beneficially. But a further question occurs: how came matter to have such properties and laws? Are these also to be considered as things of selection and institution? And if so, can we trace the reasons why the laws were established in their present form; why the properties which matter actually possesses were established and bestowed upon it? We have already attempted, in a previous part of this work, to point out some of the advantages which are secured by the existing laws of heat, light and moisture. Can we, in the same manner, point out the benefits which arise from the present constitution of those laws of matter which are mainly concerned in the production of cosmical phenomena?

It will readily be perceived that the discussion of this point must necessarily require some effort of abstract thought. The laws and properties of which we have here to speak, the laws of motion and the universal properties of matter, are so closely interwoven with our conceptions of the external world, that we have great difficulty in conceiving them not to exist, or to exist other than they are. When we press or lift a stone, we can hardly imagine that it could, by possibility, do otherwise than resist our effort by its hardness and by its heaviness, qualities so familiar to us: when we throw it, it seems inevitable that its motion should depend on the impulse we give, just as we find that it invariably does.

Nor is it easy to say how far it is really possible to suppose the fundamental attributes of matter to be different from what they are. If we, in our thoughts, attempt to divest matter of its powers of resisting and moving, it ceases to be matter, according to our conceptions, and we can no longer reason upon it with any distinctness. And yet it is certain that we can conceive the laws of hardness and weight and motion to be quite different from what they are, and can point out some of the consequences which would result from such difference. The properties of matter, even the most fundamental and universal ones, do not obtain by any absolute necessity, resembling that which belongs to the properties of geometry. A line touching a circle is *necessarily* perpendicular to a line drawn to the centre through the point touched; for it may be shown that the contrary involves a contradiction. But there is no contradiction in supposing that a body's motion should naturally diminish, or that its weight should increase in removing further from the earth's centre.

Thus the properties of matter and the laws of motion are what we find them, not by virtue of any internal necessity which we can understand. The study of such laws and properties may therefore disclose to us the character of that external agency by which we conceive them to have been determined to be what they are; and

this must be the same agency by which all other parts of the constitution of the universe were appointed and ordered.

But we can hardly expect, with regard to such subjects, that we shall be able to obtain any complete or adequate view of the reasons why these general laws are so selected, and so established. These laws are the universal basis of all operations which go on, at any moment, in every part of space, with regard to every particle of matter, organic and inorganic. All other laws and properties must have a reference to these, and must be influenced by them; both such as men have already discovered, and the far greater number which remain still unknown. The general economy and mutual relations of all parts of the universe, must be subordinate to the laws of motion and matter of which we here speak. We can easily suppose that the various processes of nature, and the dependencies of various creatures, are affected in the most comprehensive manner by these laws;—are simplified by *their* simplicity, made consistent by *their* universality; rendered regular by *their* symmetry. We can easily suppose that in this way there may be the most profound and admirable reasons for the existence of the present universal properties of matter, which we cannot apprehend in consequence of the limited nature of our knowledge, and of our faculties. For, compared with the whole extent of the universe, the whole aggregate of things and relations and connexions which exist in it, our knowledge is most narrow and partial, most shallow and superficial. We cannot suppose, therefore, that the reasons which we discover for the present form of the laws of nature go nearly to the full extent, or to the bottom of the reasons, which a more complete and profound insight would enable us to perceive. To do justice to such reasons, would require nothing less than a perfect acquaintance with the whole constitution of every part of creation; a knowledge which man has not, and so far as we can conceive, never can have.

We are certain, therefore, that our views, with regard to this part of our subject, must be imperfect and limited. Yet still man has *some* knowledge with regard to various portions of nature: and with regard to those most general and comparatively simple facts to which we now refer, his knowledge is more comprehensive, and goes deeper than it does in any other province. We conceive, therefore, that we shall not be engaged in any rash or presumptuous attempt, if we endeavour to point out some of the advantages which are secured by the present constitution of some of the general mechanical laws of nature; and to suggest the persuasion of that purpose and wise design, which the selection of such laws will thus appear to imply.

CHAPTER X.

THE LAW OF GRAVITATION.

We shall proceed to make a few observations on the Law of Gravity, in virtue of which the motions of planets about the sun, and of satellites about their planets take place; and by which also are produced the fall downwards of all bodies within our reach, and the pressure which they exert upon their supports when at rest. The identification of the latter forces with the former, and the discovery of the single law by which these forces are every where regulated, was the great discovery of Newton: and we wish to make it appear that this law is established by an intelligent and comprehensive selection.

The law of the sun's attraction upon the planets is, that this attraction varies *inversely* as the square of the distance; that is, it decreases as that square increases. If we take three points or planets of the solar system, the distances of which from the sun are in proper proportion 1, 2, 3; the attractive force which the sun at these distances exercises, is as 1, 1-4th, and 1-9th respectively. In the smaller variations of distance which occur in the elliptical motion of one planet, the variations of the force follow the same law. Moreover, not only does the sun attract the planets, but they attract each other according to the same law; the tendency to the earth which makes bodies heavy, is one of the effects of this law: and all these effects of the attractions of large masses may be traced to the attractions of the particles of which they are composed; so that the final generalization, including all the derivative laws, is, that every particle of matter in the universe attracts every other, according to the law of the inverse square of the distance.

Such is the law of universal gravitation. Now, the question is, why do either the attractions of masses, or those of their component particles, follow this law of the inverse square of the distance rather than any other? When the distance becomes 1, 2, and 3, why should not the force also become 1, 2, and 3?—or if it must be weaker at points more remote from the attracting body, why should it not be 1, a half, a third? or 1, 1-8th, 1-27th? Such laws could easily be expressed mathematically, and their consequences calculated. Can any reason be assigned why the law which we find in operation *must* obtain? Can any be assigned why it *should* obtain?

The answer to this is, that no reason, at all satisfactory, can be given why such a law must, of necessity, be what it is; but that very strong reasons can be pointed out why, for the beauty and advantage of the system, the present one is better than others. We will point out some of these reasons.

1. In the first place, the system could not have subsisted, if the force had followed a *direct* instead of an inverse law, with respect to the distance; that is, if it had increased when the distance increased. It has been sometimes said, that "all direct laws of force are excluded on account of the danger from perturbing forces;"* that if the planets had pulled at this earth, the harder the further off they were, they would have dragged it entirely out of its course. This is not an exact statement of what would happen: if the force were to be simply in the direct ratio of the distance, any number of planets might revolve in the most regular and orderly manner. Their mutual effects, which we may call perturbations if we please, would be considerable; but these perturbations would be so combined with the unperturbed motion, as to produce a new motion not less regular than the other. This curious result would follow, that every body in the system would describe, or seem to describe, about every other, an exact elliptical orbit; and that the times of the revolution of every body in its orbit would be all equal. This is proved by Newton, in the 64th proposition of the Principia. There would be nothing to prevent all the planets, on this supposition, from moving round the sun in orbits exactly circular, or nearly circular, according to the mode in which they were set in motion.

But though the perturbations of the system would not make this law inadmissible, there are other circumstances which would do so. Under this law, the gravity of bodies at the earth's surface would cease to exist. Nothing would fall or weigh downwards. The greater action of the distant sun and planets would exactly neutralize the gravity of the earth: a ball thrown from the hand, however gently, would immediately become a satellite of the earth, and would for the future accompany it in its course, revolving about it in the space of one year. All terrestrial things would float about with no principle of coherence or stability: they would obey the general law of the system, but would acknowledge no particular relation to the earth. We can hardly pretend to judge of the abstract possibility of such a system of things; but it is clear that it could not exist without an utter subversion of all that we can conceive of the economy and structure of the world which we inhabit.

With any other direct law of force, we should in like manner lose gravity, without gaining the theoretical regularity of the planetary motions which we have described in the case just considered.

2. Among *inverse* laws of the distance, (that is those according to which the force diminishes as the distance from the origin of force increases,) all which diminish the central force faster than the *cube* of the distance increases are inadmissible, because they are incompatible with the permanent revolution of a planet. Under such laws it would follow, that a planet would describe a spiral line about the

* Paley.

sun, and would either approach nearer to him perpetually, or perpetually go further off: nearly as a stone at the end of a string, when the string is whirled round, and is allowed to wrap round the hand, or to unrap from it, approaches to or recedes from the hand.

If we endeavour to compare the law of the inverse square of the distance, which really regulates the central force, with other laws, not obviously inadmissible, as for instance, the inverse simple ratio of the distance, a considerable quantity of calculation is found to be necessary in order to trace the results, and especially the perturbations in the two cases. These perturbations in the supposed case have not been calculated; such a calculation being a process so long and laborious that it is never gone through, except for the purpose of comparing the results of theory with those of observation, as we can do with regard to the law of inverse square. We can only say, therefore, that the stability of the system, and the moderate limits of the perturbations, which we know to be secured by the existing law, would not, so far as we know, be obtained by any different law.

Without going into further examination of the subject, we may observe that there are some circumstances in which the present system has a manifest superiority in its simplicity over the condition which would have belonged to it if the force had followed any other law. Thus, with the present law of gravitation the planets revolve, returning perpetually on the same track, very nearly. The earth describes an oval, in consequence of which motion she is nearer to the sun in our winter than in our summer by about one thirtieth part of the whole distance. And, as the matter now is, the nearest approach to the sun, and the farthest recess from him, occur always at the same points of the orbit. There is indeed a slight alteration in these points arising from disturbing forces, but this is hardly sensible in the course of several ages. Now if the force had followed any other law, we should have had the earth running perpetually on a new track. The greatest and least distances would have occurred at different parts in every successive revolution. The orbit would have perpetually intersected and been interlaced with the path described in former revolutions; and the simplicity and regularity which characterises the present motion would have been quite wanting.

3. Another peculiar point of simplicity in the present law of mutual attraction is this: that it makes the law of attraction for spherical masses the same as for single particles. If particles attract with forces which are inversely as the square of the distance, spheres composed of such particles, will exert a force which follows the same law. In this character the present law is singular, among all possible laws, excepting that of the direct distance which we have already discussed. If the law of the gravitation of particles had been that of the inverse simple distance, the attraction of a sphere would have been expressed by a complex series of mathematical expressions,

each representing a simple law. It is truly remarkable that the law of the inverse square of the distance, which appears to be selected as that of the *masses* of the system, and of which the mechanism is, that it arises from the action of the *particles* of the system, should lead us to the same law for the action of these particles: there is a striking *prerogative* of simplicity in the law thus adopted.

The law of gravitation actually prevailing in the solar system has thus great and clear advantages over any law widely different from it; and has moreover, in many of its consequences, a simplicity which belongs to this precise law alone. It is in many such respects a *unique* law; and when we consider that it possesses several *properties* which are *peculiar* to it, and several *advantages* which may be peculiar to it, and which are certainly nearly so; we have some ground, it would appear, to look upon its peculiarities and its advantages as connected. For the reasons mentioned in the last chapter, we can hardly expect to see fully the way in which the system is benefited by the simplicity of this law, and by the mathematical elegance of its consequences: but when we see that it has some such beauties, and some manifest benefits, we may easily suppose that our ignorance and limited capacity alone prevent our seeing that there are, for the selection of this law of force, reasons of a far more refined and comprehensive kind than we can distinctly apprehend.

4. But before quitting this subject we may offer a few further observations on the question, whether gravitation and the law of gravitation be *necessary* attributes of matter. We have spoken of the selection of this law, but is it selected? Could it have been otherwise? Is not the force of attraction a necessary consequence of the fundamental properties of matter?

This is a question which has been much agitated among the followers of Newton. Some have maintained, as Cotes, that gravity is an inherent property of all matter; others, with Newton himself, have considered it as an appendage to the essential qualities of matter, and have proposed hypotheses to account for the mode in which its effects are produced.

The result of all that can be said on the subject appears to be this: that no one can demonstrate the possibility of deducing gravity from the acknowledged fundamental properties of matter: and that no philosopher asserts, that matter has been found to exist, which was destitute of gravity. It is a property which we have no right to call *necessary* to matter, but every reason to suppose *universal*.

If we could show gravity to be a necessary consequence of those properties which we adopt as essential to our notion of matter, (extension, solidity, mobility, inertia) we might then call it also one of the essential properties. But no one probably will assert that this is the case. Its universality is a fact of observation merely. How then can a property,—in its existence so needful for the support of the universe, in its laws so well adapted to the purposes of creation,—how

came it to be thus universal? Its being found everywhere is necessary for its uses; but this is so far from being a sufficient explanation of its existence, that it is an additional fact to be explained. We have here, then, an agency most simple in its rule, most comprehensive in its influence, most effectual and admirable in its operation. What evidence could be afforded of design, by laws of mechanical action, which this law thus existing and thus operating does not afford us?

5. It is not necessary for our purpose to consider the theories which have been proposed to account for the action of gravity. They have proceeded on the plan of reducing this action to the result of pressure or impulse. Even if such theories could be established, they could not much, or at all, affect our argument; for the arrangements by which pressure or impact could produce the effects which gravity produces, must be at least as clearly results of contrivance, as gravity itself can be.

In fact, however, none of these attempts can be considered as at all successful. That of Newton is very remarkable: it is found among the Queries in the second edition of his Optics. "To show," he says, "that I do not take gravity for an essential property of bodies, I have added one question concerning its cause, choosing to propose it by way of question, because I am not yet satisfied about it for want of experiments." The hypothesis which he thus suggests is, that there is an elastic medium pervading all space, and increasing in elasticity as we proceed from dense bodies outwards: that this "causes the gravity of such dense bodies to each other: every body endeavouring to go from the denser parts of the medium towards the rarer." Of this hypothesis we may venture to say, that it is in the first place quite gratuitous; we cannot trace in any other phenomena a medium possessing these properties: and in the next place, that the hypothesis contains several suppositions which are more complex than the fact to be explained, and none which are less so. Can we, on Newton's principles conceive an elastic medium otherwise than as a collection of particles, repelling each other? and is the repulsion of such particles a simpler fact than the attraction of those which gravitate? And when we suppose that the medium becomes more elastic as we proceed from each attracting body, what cause can we conceive capable of keeping it in such a condition, except a repulsive force emanating from the body itself: a supposition at least as much requiring to be accounted for, as the attraction of the body. It does not appear, then, that this hypothesis will bear examination; although, for our purpose, the argument would be rather strengthened than weakened, if it could be established.

6. Another theory of the cause of gravity, which at one time excited considerable notice, was that originally proposed by M. Le Sage, in a memoir entitled "Lucrece Newtonien," and further illustrated by M. Prevost; according to which all space is occupied by

currents of matter, moving perpetually in straight lines, in all directions, with a vast velocity, and penetrating all bodies. When two bodies are near each other, they intercept the current which would flow in the intermediate space if they were not there, and thus receive a tendency towards each other from the pressure of the currents on their farther sides. Without examining further this curious and ingenious hypothesis, we may make upon it the same kind of observations as before;—that it is perfectly gratuitous, except as a means of explaining the phenomena; and that, if it were proved, it would still remain to be shown what necessity has caused the existence of these *two kinds* of matter; the first kind being that which is commonly called matter, and which alone affects our senses, while it is inert as to any tendency to motion; the second kind being something imperceptible to our senses, except by the effects it produces on matter of the former kind; yet exerting an impulse on every material body, permeating every portion of common matter, flowing with inconceivable velocity, in inexhaustible abundance, from every part of the abyss of infinity on one side, to the opposite part of the same abyss; and so constituted that through all eternity it can never bend its path, or return, or tarry in its course.

If we were to accept this theory, it would little or nothing diminish our wonder at the structure of the universe. We might well continue to admire the evidence of contrivance, if such a machinery should be found to produce all the effects which flow from the law of gravitation.

7. The arguments for and against the necessity of the law of the inverse square of the distance in the force of gravity, were discussed with great animation about the middle of the last century. Clairault, an eminent mathematician, who did more than almost any other person for the establishment and developement of the Newtonian doctrines, maintained, at one period of his researches, not only that the inverse square was not the *necessary* law, but also that it was not the *true* law. The occasion of this controversy was somewhat curious.

Newton and other astronomers had found that the line of the moon's *apsides* (that is of her greatest and least distances from the earth) moves round to different parts of the heavens with a velocity twice as great as that which the calculation from the law of gravitation seems at first to give. According to the theory, it appeared that this line ought to move round once in eighteen years; according to observation, it moves round once in nine years. This difference, the only obvious failure of the theory of gravitation, embarrassed mathematicians exceedingly. It is true, it was afterwards discovered that the apparent discrepancy arose from a mistake; the calculation, which is long and laborious, was supposed to have been carried far enough to get close to the truth; but it appeared afterwards that the residue which had been left out as insignificant, pro-

duced, by an unexpected turn in the reckoning, an effect as large as that which had been taken for the whole. But this discovery was not made till afterwards; and in the mean time the law of the inverse square appeared to be at fault. Clairault tried to remedy the defect by supposing that the force of the earth's gravity consisted of a large force varying as the square of the distance, and a very small force varying as the fourth power (the square of the square.) By such a supposition, observation and theory could be reconciled; but on the suggestion of it, Buffon came forward with the assertion that the force *could* not vary according to any other law than the inverse square. His arguments are rather metaphysical than physical or mathematical. Gravity, he urges, is a quality, an emanation; and all emanations are inversely as the square of the distance, as light, odours. To this Clairault replies by asking, how we know that light and odours have their intensity inversely as the square of the distance from their origin: not, he observes, by measuring the intensity, but by *supposing* these effects to be material emanations. But who, he asks, supposes gravity to be a material emanation *from* the attracting body.

Buffon again pleads that so many facts prove the law of the inverse square, that a single one, which occurs to interfere with this agreement, must be in some manner capable of being explained away. Clairault replies, that the facts do *not* prove this law to obtain exactly; that small effects, of the same order as the one under discussion, have been neglected; and that therefore the law is only known to be true, *as far* as such an approximation goes, and no farther.

Buffon then argues, that there can be no such additional fraction of the force, following a different law, as Clairault supposes: for what, he asks, is there to determine the magnitude of the fraction to one amount rather than another? why should nature select for it any particular magnitude? To this it is replied, that, whether we can explain the fact or not, nature does select certain magnitudes in preference to others: that where we ascertain she does this, we are not to deny the fact because we cannot assign the grounds of her preference. What is there, it is asked, to determine the magnitude of the whole force at any fixed distance? We cannot tell; yet the force is of a certain definite intensity and no other.

Finally Clairault observes, that we have, in cohesion, capillary attraction, and various other cases, examples of forces varying according to other laws than the inverse square; and that therefore this cannot be the only possible law.

The discrepancy between observation and theory which gave rise to this controversy was removed, as has been already stated, by a more exact calculation: and thus, as Laplace observes, in this case the metaphysician turned out to be right and the mathematician to be wrong. But most persons, probably, who are familiar with such

trains of speculation, will allow, that Clairault had the best of the argument, and that the attempts to show the law of gravitation to be necessarily what it is, are fallacious and unsound.

8. We may observe, however, that the law of gravitation according to the inverse square of the distance, which thus regulates the motions of the solar system, is not confined to that province of the universe, as has been shown by recent researches. It appears by the observations and calculations of Sir John Herschel, that several of the stars, called *double stars*, consist of a pair of luminous bodies which revolve above each other in ellipses, in such a manner as to show that the force, by which they are attracted to each other, varies according to the law of the inverse square. We thus learn a remarkable fact concerning bodies which seemed so far removed that no effort of our science could reach them; and we find that the same law of mutual attraction which we have before traced to the farthest bounds of the solar system, prevails also in spaces at a distance compared with which the orbit of Saturn shrinks into a point. The establishment of such a truth certainly suggests, as highly probable, the prevalence of this law among all the bodies of the universe. And we may therefore suppose, that the same ordinance which gave to the parts of our system that rule by which they fulfil the purposes of their creation, impressed the same rule on the other portions of matter which are scattered in the most remote parts of the universe; and thus gave to their movements the same grounds of simplicity and harmony which we find reason to admire, as far as we can acquire any knowledge of our own more immediate neighbourhood.

CHAPTER XI.

THE LAWS OF MOTION.

We shall now make a few remarks on the general Laws of Motion by which all mechanical effects take place. Are we to consider these as instituted laws? and if so, can we point out any of the reasons which we may suppose to have led to the selection of those laws which really exist?

The observations formerly made concerning the inevitable narrowness and imperfection of our conclusions on such subjects, apply here, even more strongly than in the case of the law of gravitation. We can hardly conceive matter divested of these laws; and we cannot perceive or trace a millionth part of the effects which they produce. We cannot, therefore, expect to go far in pointing out the advantages of these laws such as they now obtain.

It would be easy to show that the fundamental laws of motion, in whatever form we state them, possess a very pre-eminent simplicity, compared with almost all others, which we might imagine as existing. This simplicity has indeed produced an effect on men's minds which, though delusive, appears to be very natural; several writers have treated these laws as self-evident, and necessarily flowing from the nature of our conceptions. We conceive that this is an erroneous view, and that these laws are known to us to be what they are, by experience only; that they might, so far as we can discern, have been any others. They appear therefore to be selected for their fitness to answer their purposes; and we may, perhaps, be able to point out some instances in which this fitness is apparent to us.

Newton, and many English plilosophers, teach the existence of *three* separate fundamental laws of motion, while most of the eminent mathematicians of France reduce these to *two*, the law of inertia and the law that force is proportional to velocity. As an example of the views which we wish to illustrate, we may take the law of inertia, which is identical with Newton's first Law of Motion. This law asserts, that a body at rest continues at rest, and that a body in motion goes on moving with its velocity and direction unchanged, except so far as it is acted on by extraneous forces.*

We conceive that this law, simple and universal as it is, cannot be shown to be necessarily true. It might be difficult to discuss this point in general terms with any clearness; but let us take the only example which we know of a motion absolutely uniform, in consequence of the absence of any force to accelerate or retard it;—this motion is the rotation of the earth on its axis.

1. It is scarcely possible that discussions on such subjects should not have a repulsive and scholastic aspect, and appear like disputes about words rather than things. For mechanical writers have exercised all their ingenuity so as to circumscribe their notions and so to define their terms that these fundamental truths should be expressed in the simplest manner: the consequence of which has been, that they have been made to assume the appearance rather of identical assertions than of general facts of experience. But in order to avoid this inconvenience, as far as may be, let us take the *first law of motion* as exemplified in a particular case, the rotation of the earth. Of all the motions with which we are acquainted this is alone invariable. Each day, measured by the passages of the stars, is so precisely of the same length that, according to Laplace's calculations, it is impossi-

* If the Laws of Motion are stated as *three*, which we conceive to be the true view of the subject, the other two, as applied in mechanical reasonings, are the following:

Second Law. When a force acts on a body in motion, it produces the same effect as if the same force acted on a body at rest.

Third Law. When a force of the nature of pressure produces motion, the velocity produced is proportional to the force, other things being equal.

ble that a difference of one-hundredth of a second of time should have obtained between the length of the day in the earliest ages and at the present time. Now why is this? How is this very remarkable uniformity preserved in this particular phenomenon, while all the other motions of the system are subject to inequalities? How is it that in the celestial machine no retardation takes place by the lapse of time, as would be the case in any machine which it would be possible for human powers to construct? The answer is, that in the earth's revolution on her axis no cause operates to retard the speed, like the imperfection of materials, the friction of supports, the resistance of the ambient medium; impediments which cannot, in any human mechanism, however perfect, be completely annihilated. But here we are led to ask again, why should the speed continue the same when not affected by an extraneous cause? why should it not languish and decay of itself by the mere lapse of time? That it might do so, involves no contradiction, for it was the common, though erroneous, belief of all mechanical speculators, to the time of Galileo. We can conceive velocity to diminish in proceeding from a certain point of time, as easily as we can conceive force to diminish in proceeding from a certain point of space, which in attractive forces really occurs. But, it is sometimes said, the *motion* (that is the velocity) *must* continue the same from one instant to another, for there is nothing to change it. This appears to be taking refuge in words. We may call the velocity, that is the speed of a body, its motion; but we cannot, by giving it this name, make it a *thing* which has any *à priori* claim to permanence, much less any self-evident constancy. Why must the speed of a body, left to itself, continue the same, any more than its temperature. Hot bodies grow cooler of themselves, why should not quick bodiés go slower of themselves? Why must a body describe 1000 feet in the next second because it has described 1000 feet in the last? Nothing but experience, under proper circumstances, can inform us whether bodies, abstracting from external agency, do move according to such a rule. We find that they do so, we learn that all diminution of their speed which ever takes place, can be traced to external causes. Contrary to all that men had guessed, motion appears to be of itself endless and unwearied. In order to account for the unalterable permanence of the length of our day, all that is requisite is to show that there is no let or hindrance in the way of the earth's rotation;—no resisting medium or alteration of size,—she "spinning *sleeps*" on her axle, as the poet expresses it, and may go on sleeping with the same regularity for ever, so far as the experimental properties of motion are concerned.

Such is the necessary consequence of the first law of motion; but the law itself has no necessary existence, so far as we can see. It was discovered only after various perplexities and false conjectures of speculators on mechanics. We have learnt that it is so, but we have not learnt, nor can any one undertake to teach us, that it must

have been so. For aught we can tell, it is one among a thousand equally possible laws, which might have regulated the motions of bodies.

2. But though we have thus no reason to consider this as the only possible law, we have good reason to consider it as the best, or at least as possessing all that we can conceive of advantage. It is the *simplest* conceivable of such laws. If the velocity had been compelled to change with the time, there must have been a law of the change, and the kind and amount of this change must have been determined by its dependence on the time and other conditions. This, though quite supposable, would undoubtedly have been more complex than the present state of things. And though complexity does not appear to embarrass the operations of the laws of nature, and is admitted, without scruple, when there is reason for it, simplicity is the usual character of such laws, and appears to have been a ground of selection in the formation of the universe, as it is a mark of beauty to us in our contemplation of it.

But there is a still stronger apparent reason for the selection of this law of the preservation of motion. If the case had been otherwise, the universe must necessarily in the course of ages have been reduced to a state of rest, or at least to a state not sensibly differing from it. If the earth's motion, round its axis, had slackened by a very small quantity, for instance, by a hundredth of a second in a revolution, and in this proportion continued, the day would have been already lengthened by six hours in the 6000 years which have elapsed since the history of the world began; and if we suppose a longer period to precede or to follow, the day might be increased to a month or to any length. All the adaptations which depend on the length of the day would consequently be deranged. But this would not be all; for the same law of motion is equally requisite for the preservation of the annual motion of the earth. If her motion were retarded by the establishment of any other law instead of the existing one, she would wheel nearer and nearer to the sun at every revolution, and at last reach the centre, like a falling hoop. The same would happen to the other planets; and the whole solar system would, in the course of a certain period, be gathered into a heap of matter without life or motion. In the present state of things on the other hand, the system, as we have already explained, is, by a combination of remarkable provisions, calculated for an almost indefinite existence, of undiminished fitness for its purposes.

There are, therefore, manifest reasons, why, of all laws which could occupy the place of the first law of motion, the one which now obtains is the only one consistent with the durability and uniformity of the system;—the one, therefore, which we may naturally conceive to be selected by a wise contriver. And as, along with this, it has appeared that we have no sort of right to attribute the

establishment of this law to anything but selection, we have here a striking evidence, to lead us to a perception of that Divine mind, by which means so simple are made to answer purposes so extensive and so beneficial.

CHAPTER XII.

FRICTION.*

We shall not pursue this argument of the last chapter, by considering the other laws of motion in the same manner as we have there considered the first, which might be done. But the facts which form exceptions and apparent contradictions to the first law of which we have been treating, and which are very numerous, offer, we conceive, an additional exemplification of the same argument; and this we shall endeavour to illustrate.

The rule that a body naturally moves for ever with an undiminished speed, is so far from being obviously true, that it appears on a first examination to be manifestly false. The hoop of the school boy, left to itself, runs on a short distance, and then stops; his top spins a little while, but finally flags and falls; all motion on the earth appears to decay by its own nature; all matter which we move appears to have a perpetual tendency to divest itself of the velocity which we communicate to it. How is this reconcileable with the first law of motion on which we have been insisting?

It is reconciled principally by considering the effect of *Friction*. Among terrestrial objects friction exerts an agency almost as universal and constant as the laws of motion themselves; an agency which completely changes and disguises the results of those laws. We shall consider some of these effects.

It is probably not necessary to explain at any length the nature and operation of friction. When a body cannot move without causing two surfaces to rub together, this rubbing has a tendency to diminish the body's motion or to prevent it entirely. If the body of a carriage be placed on the earth without the wheels, a considerable force will be requisite in order to move it at all: it is here the friction against the ground which obstructs the motion. If the carriage be placed on its wheels, a much less force will move

* Though Friction is not concerned in any cosmical phenomena, we have thought this the proper place to introduce the consideration of it; since the contrast between the cases in which it does act, and those in which it does not, is best illustrated by a comparison of cosmical with terrestrial motions.

it, but if moved it will soon stop: it is the friction at the ground and at the axles which stops it: placed on a level rail road, with well made and well oiled wheels, and once put in motion, it might run a considerable distance alone, for the friction is here much less; but there *is* friction, and therefore the motion would after a time cease.

1. The friction which we shall principally consider is the friction which *prevents* motion. So employed, friction is one of the most universal and important agents in the mechanism of our daily comforts and occupations. It is a force which is called into play to an extent incomparably greater than all the other forces with which we are concerned in the course of our daily life. We are dependent upon it at every instant and in every action: and it is not possible to enumerate the ways in which it serves us; scarcely even to suggest a sufficient number of them to give us a true notion of its functions.

What can appear a more simple operation than standing and walking? yet it is easy to see that without the aid of friction these simple actions would scarcely be possible. Every one knows how difficult and dangerous they are when performed on smooth ice. In such a situation we cannot always succeed in standing: if the ice be very smooth, it is by no means easy to walk, even when the surface is perfectly level; and if it were ever so little inclined, no one would make the attempt. Yet walking on the ice and on the ground differ only in our experiencing more friction in the latter case. We say *more*, for there is a considerable friction even in the case of ice, as we see by the small distance which a stone slides when thrown along the surface. It is this friction of the earth which, at every step we take, prevents the foot from sliding back; and thus allows us to push the body and the other foot forwards. And when we come to violent bodily motions, to running, leaping, pulling or pushing objects, it is easily seen how entirely we depend upon the friction of the ground for our strength and force. Every one knows how completely powerless we become in any of these actions by the *foot slipping*.

In the same manner it is the friction of objects to which the hand is applied, which enables us to hold them with any degree of firmness. In some contests it was formerly the custom for the combatants to rub their bodies with oil, that the adversary might not be able to keep his grasp. If the pole of the boatman, the rope of the sailor, were thus smooth and lubricated, how weak would be the thrust and the pull! Yet this would only be the removal of friction.

Our buildings are no less dependent on this force for their stability. Some edifices are erected without the aid of cement; and if the stones be large and well squared, such structures may be highly substantial and durable; even when rude and slight, houses so built

answer the purposes of life. These are entirely upheld by friction, and without that agent they would be thrown down by the Zephyr, far more easily than if all the stones were lumps of ice with a thawing surface. But even in cases where cement *binds* the masonry, it does not take the duty of *holding* it together. In consequence of the existence of friction, there is no constant tendency of the stones to separate; they are in a state of repose. If this were not so, if every shock and every breeze required to be counteracted by the cement, no composition exists which would long sustain such a wear and tear. The cement excludes the corroding elements, and helps to resist extraordinary violence; but it is friction which gives the habitual state of rest.

We are not to consider friction as a *small* force, slightly modifying the effects of other agencies. On the contrary its amount is in most cases very great. When a body lies loose on the ground, the friction is equal to one third or one half, in some cases the whole of its weight. But in cases of bodies supported by oblique pressure, the amount is far more enormous. In the arch of a bridge, the friction which is called into play between two of the vaulting stones, may be equal to the whole weight of the bridge. In such cases this conservative force is so great, that the common theory, which neglects it, does not help us even to guess what will take place. According to the theory, certain forms of arches only will stand, but in practice almost any form will stand, and it is not easy to construct a model of a bridge which will fall.

We may see the great force of friction in the *brake*, by which a large weight running down a long inclined plane has its motion moderated and stopped; in the windlass, where a few coils of the rope round a cylinder sustain the stress and weight of a large iron anchor; in the nail or screw which holds together large beams; in the mode of raising large blocks of granite by an iron rod driven into a hole in the stone. Probably no greater forces are exercised in any processes in the arts than the force of friction; and it is always employed to produce rest, stability, moderate motion. Being always ready and never wearied, always at hand and augmented with the exigency, it regulates, controls, subdues all motions:—counteracts all other agents;—and finally gains the mastery over all other terrestrial agencies, however violent, frequent, or long continued. The perpetual action of all other terrestrial forces appears, on a large scale, only as so many interruptions of the constant and stationary rule of friction.

The objects which every where surround us, the books or dishes which stand on our tables, our tables and chairs themselves, the loose clods and stones in the field, the heaviest masses produced by nature or art, would be in a perpetual motion, quick or slow according to the forces which acted on them, and to their size, if it were not for the tranquillizing and steadying effects of the agent we are

considering. Without this, our apartments, if they kept their shape, would exhibit to us articles of furniture, and of all other kinds, sliding and creeping from side to side with every push and every wind, like loose objects in a ship's cabin, when she is changing her course in a gale.

Here, then, we have a force, most extensive and incessant in its operation, which is absolutely essential to the business of this terrestrial world, according to any notion which we can form. The more any one considers its effects, and the more he will find how universally dependent he is upon it, in every action of his life; resting or moving, dealing with objects of art or of nature, with instruments of enjoyment or of action.

2. Now we have to observe concerning this agent, Friction, that we have no ground for asserting it to be a necessary result of other properties of matter, for instance, of their solidity and coherency. Philosophers have not been able to deduce the laws of friction from the other known properties of matter, nor even to explain what we know experimentally of such laws, (which is not much,) without introducing new hypotheses concerning the surfaces of bodies, &c.—hypotheses which are not supplied us by any other set of phenomena. So far as our knowledge goes, friction is a separate property, and may be conceived to have been bestowed upon matter for particular purposes. How well it answers the purpose of fitting matter for the uses of the daily life of man, we have already seen.

We may make suppositions as to the mode in which friction is connected with the texture of bodies; but little can be gained for philosophy, or for speculation of any kind, by such conjectures respecting unknown connexions. If, on the other hand, we consider this property of friction, and find that it prevails there, and there only, where the general functions, analogies, and relations of the universe require it, we shall probably receive a strong impression that it was introduced into the system of the world *for a purpose.*

3. It is very remarkable that this force, which is thus so efficacious and discharges such important offices in all earthly mechanism, disappears altogether when we turn to the mechanism of the heavens. All motions on the earth soon stop;—a machine which imitates the movements of the stars cannot go long without winding up: but the stars themselves have gone on in their courses for ages, with no diminution of their motions, and offer no obvious prospect of any change. This is so palpable a fact, that the first attempts of men to systematise their mechanical notions were founded upon it. The ancients held that motions were to be distinguished into *natural* motions and *violent,*—the former go on without diminution—the latter are soon extinguished;—the motions of the stars are of the former kind;—those of a stone thrown, and in short all terrestrial motions, of the latter. Modern philosophers maintain that the laws of motion are the same for celestial and terrestrial bodies;—that all

motions are *natural* according to the above description ;—but that in terrestrial motions friction comes in and alters their character.—destroys them so speedily that they appear to have existed only during an effort. And that this is the case will not now be contested. Is it not then somewhat remarkable that the same laws which produce a state of permanent motion in the heavens, should, on the earth, give rise to a condition in which rest is the rule and motion the exception? The air, the waters, and the lighter portions of matter are, no doubt, in a state of perpetual motion; over these friction has no empire: yet even their motions are interrupted, alternate, variable, and on the whole slight deviations from the condition of equilibrium. But in the solid parts of the globe, rest predominates incomparably over motion: and this, not only with regard to the portions which cohere as parts of the same solid; for the whole surface of the earth is covered with loose masses, which, if the power of friction were abolished, would rush from their places and begin one universal and interminable dance, which would make the earth absolutely uninhabitable.

If, on the other hand, the dominion of friction were extended in any considerable degree into the planetary spaces, there would soon be an end of the system. If the planet had moved in a fluid, as the Cartesians supposed, and if this fluid had been subject to the rules of friction which prevail in terrestrial fluids, their motions could not have been of long duration. The solar system must soon have ceased to be a system of revolving bodies.

But friction is neither abolished on the earth, nor active in the heavens. It operates where it is wanted, it is absent where it would be prejudicial. And both these circumstances occasion, in a remarkable manner, the steadiness of the course of nature. The stable condition of the objects in man's immediate neighbourhood, and the unvarying motions of the luminaries of heaven, are alike conducive to his well-being. This requires that he should be able to depend upon a fixed order of place, a fixed course of time. It requires, therefore, that terrestrial objects should be affected by friction, and that celestial should not; as is the case, in fact. What further evidence of benevolent design could this part of the constitution of the universe supply?

4. There is another view which may be taken of the forces which operate on the earth to produce permanency or change. Some parts of the terrestrial system are under the dominion of powers which act energetically to prevent all motion, as the crystalline forces by which the parts of rocks are bound together; other parts are influenced by powers which produce a perpetual movement and change in the matter of which they consist; thus plants and animals are in a constant state of internal movement, by the agency of the vital forces. In the former case rigid immutability, in the latter perpetual developement, are the tendencies of the agencies

employed. Now in the case of objects affected by friction, we have a kind of intermediate condition, between the constantly fixed and the constantly moveable. Such objects can and do move; but they move but for a short time if left to the laws of nature. When at rest, they can easily be put in motion, but still not with unlimited ease; a certain finite effort, different in different cases, is requisite for their purpose. Now this immediate condition, this capacity of receiving readily and alternately the states of rest and motion, is absolutely requisite for the nature of man, for the exertion of will, of contrivance, of foresight, as well as for the comfort of life and the conditions of our material existence. If all objects were fixed and immoveable, as if frozen into one mass; or if they were susceptible of such motions only as are found in the parts of vegetables, we attempt in vain to conceive what would come of the business of the world. But besides the state of a particle which cannot be moved, and of a particle which cannot be stopped, we have the state of a particle moveable but not moved; or moved, but moved only while we choose: and this state is that about which the powers, the thoughts, and the wants of man are mainly conversant.

Thus the forces by which solidity and by which organic action are produced, the laws of permanence and of developement, do not bring about all that happens. Besides these, there is a mechanical condition, that of a body exposed to friction, which is neither one of absolute permanency nor one naturally progressive; but is yet one absolutely necessary to make material objects capable of being instruments and aids to man; and this is the condition of by far the greater part of terrestrial things. The habitual course of events with regard to motion and rest is not the same for familiar moveable articles, as it is for the parts of the mineral, or of the vegetable world, when left to themselves; such articles are in a condition far better adapted than any of those other conditions would be, to their place and purpose. Surely this shows us an *adaptation*, and adjustment, of the constitution of the material world to the nature of man. And as the organization of plants cannot be conceived otherwise than as having their life and growth for its object, so we cannot conceive that friction should be one of the leading agencies in the world in which man is placed, without supposing that it was intended to be of use when man should walk and run, and build houses and ships, and bridges, and execute innumerable other processes, all of which would be impossible, admirably constituted as man is in other respects, if friction did not exist. And believing, as we conceive we cannot but believe, that the laws of motion and rest were thus given with reference to their ends, we perceive in this instance, as in others, how wide and profound this reference is, how simple in its means, how fertile in its consequences, how effective in its details.

BOOK III.

RELIGIOUS VIEWS.

The contemplation of the material universe exhibits God to us as the author of the laws of material nature; bringing before us a wonderful spectacle, in the simplicity, the comprehensiveness, the mutual adaptation of these laws, and in the vast variety of harmonious and beneficial effects produced by their mutual bearing and combined operation. But it is the consideration of the moral world, of the results of our powers of thought and action, which leads us to regard the Deity in that light in which our relation to him becomes a matter of the highest interest and importance. We perceive that man is capable of referring his actions to principles of right and wrong; that both his faculties and his virtues may be unfolded and advanced by the discipline which arises from the circumstances of human society; that good men can be discriminated from the bad, only by a course of trial, by struggles with difficulty and temptation; that the best men feel deeply the need of relying, in such conflicts, on the thought of a superintending Spiritual Power; that our views of justice, our capacity for intellectual and moral advancement, and a crowd of hopes and anticipations which rise in our bosoms unsought, and cling there with inexhaustible tenacity, will not allow us to acquiesce in the belief that this life is the end of our existence. We are thus led to see that our relation to the Superintender of our moral being, to the Depository of the supreme law of just and right, is a relation of incalculable consequence. We find that we cannot be permitted to be merely contemplators and speculators with regard to the Governor of the moral world: we must obey His will; we must turn our affections to Him; we must advance in His favour; or we offend against the nature of our position in the scheme of which He is the author and sustainer.

It is far from our purpose to represent natural religion, as of itself sufficient for our support and guidance; or to underrate the manner in which our views of the Lord of the universe have been, much more, perhaps, than we are sometimes aware, illustrated and confirmed by lights derived from revelation. We do not here speak of the manner in which men have come to believe in God, as the Governor of the moral world; but of the fact, that by the aid of

one or both of these two guides, Reason or Revelation, reflecting persons in every age have been led to such a belief. And we conceive it may be useful to point out some connexion between such a belief of a just and holy Governor, and the conviction, which we have already endeavoured to impress upon the reader, of a wise and benevolent Creator of the physical world. This we shall endeavour to do in the present book.

At the same time that men have thus learned to look upon God as their Governor and Judge, the source of their support and reward, they have also been led, not only to ascribe to him power and skill, knowledge and goodness, but also to attribute to him these qualities in a mode and degree excluding all limit:—to consider him as almighty, all-wise, of infinite knowledge and inexhaustible goodness; every where present and active, but incomprehensible by our minds, both in the manner of his agency, and the degree of his perfections. And this impression concerning the Deity appears to be that which the mind receives from all objects of contemplation and all modes of advance towards truth. To this conception it leaps with alacrity and joy, and in this it acquiesces with tranquil satisfaction and growing confidence; while any other view of the nature of the Divine Power which formed and sustained the world, is incoherent and untenable, exposed to insurmountable objections and intolerable incongruities. We shall endeavour to show that the modes of employment of the thoughts to which the well conducted study of nature gives rise, do tend, in all their forms, to produce or strengthen this impression on the mind; and that such an impression, and no other, is consistent with the widest views and most comprehensive aspects of nature and of philosophy, which our Natural Philosophy opens to us. This will be the purpose of the latter part of the present book. In the first place we shall proceed with the object first mentioned, the connexion which may be perceived between the evidences of creative power, and of moral government, in the world.

CHAPTER I.

THE CREATOR OF THE PHYSICAL WORLD IS THE GOVERNOR OF THE MORAL WORLD.

With our views of the moral government of the world and the religious interests of man, the study of material nature is not and cannot be directly and closely connected. But it may be of some service to trace in these two lines of reasoning, seemingly so re-

mote, a manifest convergence to the same point, a demonstrable unity of result. It may be useful to show that we are thus led, not to two rulers of the universe, but to one God;—to make it appear that the Creator and Preserver of the world is also the Governor and Judge of men;—that the Author of the Laws of Nature is also the Author of the Law of Duty;—that He who regulates corporeal things by properties of attraction and affinity and assimilating power, is the same Being who regulates the actions and conditions of men, by the influence of the feeling of responsibility, the perception of right and wrong, the hope of happiness, the love of good.

The conviction that the Divine attributes which we are taught by the study of the material world, and those which we learn from the contemplation of man, as a responsible agent, belong to the Divine Being, will be forced upon us, if we consider the manner in which all the parts of the universe, the corporeal and intellectual, the animal and moral, are connected with each other. In each of these provinces of creation we trace refined adaptations and arrangements which lead us to the Creator and Director of so skilful a system; but these provinces are so intermixed, these different trains of contrivances so interwoven, that we cannot, in our thoughts, separate the author of one part from the author of another. The Creator of the Heavens and of the Earth, of the inorganic and of the organic world, of animals and of man, of the affections and the conscience, appears inevitably to be one and the same God.

We will pursue this reflection a little more into detail.

1. The *atmosphere* is a mere mass of fluid floating on the surface of the ball of the earth; it is one of the inert and inorganic portions of the universe, and must be conceived to have been formed by the same Power which formed the solid mass of the earth and all other parts of the solar system. But how far is the atmosphere from being inert in its effects on organic beings, and unconnected with the world of life! By what wonderful adaptations of its mechanical and chemical properties, and of the vital powers of plants, to each other, are the developement and well-being of plants and animals secured! The creator of the atmosphere must have been also the creator of plants and animals: we cannot for an instant believe the contrary. But the atmosphere is not only subservient to the life of animals, and of man among the rest; it is also the vehicle of voice; it answers the purpose of intercourse; and, in the case of man, of rational intercourse. We have seen how remarkably the air is fitted for this office; the construction of the organs of articulation, by which they are enabled to perform their part of the work, is, as is well known, a most exquisite system of contrivances. But though living in an atmosphere capable of transmitting articulate sound, and though provided with organs fitted to articulate, man would never attain to the use of language, if he were not also endowed with another set of faculties. The powers of abstraction and generalisation, memory

and reason, the tendencies which occasion the inflections and combinations of words, are all necessary to the formation and use of language. Are not these parts of the same scheme of which the bodily faculties by which we are able to speak are another part? Has man his mental powers independently of the creator of his bodily frame? To what purpose then, or by what cause was the curious and complex machinery of the tongue, the glottis, the larynx produced? These are useful for speech, and full of contrivances which suggest such a use as the end for which those organs were constructed. But speech appears to have been no less contemplated in the intellectual structure of man. The processes of which we have spoken, generalization, abstraction, reasoning, have a close dependence on the use of speech. These faculties are presupposed in the formation of language, but they are developed and perfected by the use of language. The mind of man then, with all its intellectual endowments, is the work of the same artist by whose hands his bodily frame was fashioned; as his bodily faculties again are evidently constructed by the maker of those elements on which their action depends. The creator of the atmosphere and of the material universe is the creator of the human mind, and the author of those wonderful powers of thinking, judging, inferring, discovering, by which we are able to reason concerning the world in which we are placed; and which aid us in lifting our thoughts to the source of our being himself.

2. *Light*, or the means by which light is propagated, is another of the inorganic elements which forms a portion of the mere material world. The luminiferous ether, if we adopt that theory, or the fluid light of the theory of emission, must indubitably pervade the remotest regions of the universe, and must be supposed to exist, as soon as we suppose the material parts of the universe to be in existence. The origin of light then must be at least as far removed from us as the origin of the solar system. Yet how closely connected are the properties of light with the structure of our own bodies! The mechanism of the organs of vision and the mechanism of light are, as we have seen, most curiously adapted to each other. We must suppose, then, that the same power and skill produced one and the other of these two sets of contrivances, which so remarkably *fit into* each other. The creator of light is the author of our visual powers. But how small a portion does mere visual perception constitute of the advantages which we derive from vision! We possess ulterior faculties and capacities by which sight becomes a source of happiness and good to man. The sense of beauty, the love of art, the pleasure arising from the contemplation of nature, are all dependent on the eye; and we can hardly doubt that these faculties were bestowed on man to further the best interests of his being. The sense of beauty both animates and refines his domestic tendencies; the love of art is a powerful instrument for raising him above the mere cravings and satisfactions of his animal nature; the expansion of mind which rises in us at the sight of the

starry sky, the cloud-capt mountain, the boundless ocean, seems intended to direct our thoughts by an impressive though indefinite feeling, to the Infinite Author of All. But if these faculties be thus part of the scheme of man's inner being, given him by a good and wise creator, can we suppose that this creator was any other than the creator also of those visual organs, without which the faculties could have no operation and no existence? As clearly as light and the eye are the work of the same author, so clearly also do our capacities for the most exalted visual pleasures, and the feelings flowing from them, proceed from the same Divine Hand.

3. The creator of the earth must be conceived to be the author also of all those qualities in the soil, chemical and whatever else, by which it supports vegetable life, under all the modifications of natural and artificial condition. Among the attributes which the earth thus possesses, there are some which seem to have an especial reference to man in a state of society. Such are the powers of the earth to increase its produce under the influence of cultivation, and the necessary existence of property in land, in order that this cultivation may be advantageously applied; the rise, under such circumstances, of a *surplus* produce, of a quantity of subsistence exceeding the wants of the cultivators alone; and the consequent possibility of inequalities of rank, and of all the arrangements of civil society. These are all parts of the constitution of the earth. But these would all remain mere idle possibilities, if the nature of man had not a corresponding direction. If man had not a social and economical tendency, a disposition to congregate and co-operate, to distribute possessions and offices among the members of the community, to make and obey and enforce laws, the earth would in vain be ready to respond to the care of the husbandman. Must we not then suppose that this attribute of the earth was bestowed upon it by Him who gave to man those corresponding attributes, through which the apparent niggardliness of the soil is the source of general comfort and security, of polity and law? Must we not suppose that He who created the soil also inspired man with those social desires and feelings which produce cities and states, laws and institutions, arts and civilization; and that thus the apparently inert mass of earth is a part of the same scheme as those faculties and powers with which man's moral and intellectual progress is most connected?

4. Again:—It will hardly be questioned that the author of the material elements is also the author of the structure of animals, which is adapted to and provided for by the constitution of the elements in such innumerable ways. But the author of the bodily structure of animals must also be the author of their instincts, for without these the structure would not answer its purpose. And these instincts frequently assume the character of affections in a most remarkable manner. The love of offspring, of home, of companions, are often displayed by animals, in a way that strikes the most indifferent ob-

server; and yet these affections will hardly be denied to be a part of the same scheme as the instincts by which the same animals seek food and the gratifications of sense. Who can doubt that the anxious and devoted affection of the mother-bird for her young after they are hatched, is a part of the same system of Providence as the instinct by which she is impelled to sit upon her eggs? and this, of the same by which her eggs are so organized that incubation leads to the birth of the young animal? Nor, again, can we imagine that while the structure and affections of animals belong to one system of things, the affections of man, in many respects so similar to those of animals, and connected with the bodily frame in a manner so closely analogous, can belong to a different scheme. Who, that reads the touching instances of maternal affection, related so often of the women of all nations, and of the females of all animals, can doubt that the principle of action is the same in the two cases, though enlightened in one of them by the rational faculty? And who can place in separate provinces the supporting and protecting love of the father and of the mother? or consider as entirely distinct from these, and belonging to another part of our nature, the other kinds of family affection? or disjoin man's love of his home, his clan, his tribe, his country, from the affection which he bears to his family? The love of offspring, home, friends, in man, is then part of the same system of contrivances of which bodily organization is another part. And thus the author of our corporeal frame is also the author of our capacity of kindness and resentment, of our love and of our wish to be loved, of all the emotions which bind us to individuals, to our families, and to our kind.

It is not necessary here to follow out and classify these emotions and affections: or to examine how they are combined and connected with our other motives of action, mutually giving and receiving strength and direction. The desire of esteem, of power, of knowledge, of society, the love of kindred, of friends, of our country, are manifestly among the main forces by which man is urged to act and to abstain. And as these parts of the constitution of man are clearly intended, as we conceive, to impel him in his appointed path; so we conceive that they are no less clearly the work of the same great Artificer who created the heart, the eye, the hand, the tongue, and that elemental world in which, by means of these instruments, man pursues the objects of his appetites, desires, and affections.

5. But if the Creator of the world be also the author of our intellectual powers, of our feeling for the beautiful and the sublime, of our social tendencies, and of our natural desires and affections, we shall find it impossible not to ascribe also to Him the higher directive attributes of our nature, the conscious and the religious feeling, the reference of our actions to the rule of duty and to the will of God.

It would not suit the plan of the present treatise to enter into any

detailed analysis of the connexion of these various portions of our moral constitution. But we may observe that the existence and universality of the conception of duty and right cannot be doubted, however men may differ as to its original or derivative nature. All men are perpetually led to form judgments concerning actions, and emotions which lead to action, as right or wrong; as what they *ought* or *ought not* to do or feel. There is a faculty which approves and disapproves, acquits or condemns the workings of our other faculties. Now, what shall we say of such a judiciary principle, thus introduced among our motives to action? Shall we conceive that while the other springs of action are balanced against each other by our Creator, this, the most pervading and universal regulator, was no part of the original scheme? That—while the love of animal pleasures, of power, of fame, the regard for friends, the pleasure of bestowing pleasure, were infused into man as influences by which his course of life was to be carried on, and his capacities and powers developed and exercised;—this reverence for a moral law, this acknowledgment of the obligation of duty,—a feeling which is every where found, and which may become a powerful, a predominating motive of action,—was given for no purpose, and belongs not to the design? Such an opinion would be much as if we should acknowledge the skill and contrivance manifested in the other parts of a ship, but should refuse to recognise the rudder as exhibiting any evidence of a purpose. Without the reverence which the opinion of right inspires, and the scourge of general disapprobation inflicted on that which is accounted wicked, society could scarcely go on; and certainly the feelings and thoughts and characters of men could not be what they are. Those impulses of nature which involve no acknowledgment of responsibility, and the play and struggle of interfering wishes, might preserve the species in some shape of existence, as we see in the case of brutes. But a person must be strangely constituted, who, living amid the respect for law, the admiration for what is good, the order and virtues and graces of civilized nations, (all which have their origin in some degree in the feeling of responsibility) can maintain that all these are casual and extraneous circumstances, no way contemplated in the formation of man; and that a condition in which there should be no obligation in law, no merit in self-restraint, no beauty in virtue, is equally suited to the powers and the nature of man, and was equally contemplated when those powers were given him.

If this supposition be too extravagant to be admitted, as it appears to be, it remains then that man, intended, as we have already seen from his structure and properties, to be a discoursing, social being, acting under the influence of affections, desires, and purposes, was also intended to act under the influence of a sense of duty; and that the acknowledgment of the obligation of a moral law is as much part of his nature, as hunger or thirst, maternal love or the desire of

power; that, therefore, in conceiving man as the work of a Creator, we must imagine his powers and character given him with an intention on the Creator's part that this sense of duty should occupy its place in his constitution as an active and thinking being: and that this directive and judiciary principle is a part of the work of the same Author who made the elements to minister to the material functions, and the arrangements of the world to occupy the individual and social affections of his living creatures.

This principle of conscience, it may further be observed, does not stand upon the same level as the other impulses of our constitution by which we are prompted or restrained. By its very nature and essence, it possesses a supremacy over all others. "Your obligation to obey this law is its being the law of your nature. That your conscience approves of and attests such a course of action is itself alone an obligation. Conscience does not alone offer itself to show us the way we should walk in, but it likewise carries its own authority with it, that it is our natural guide: the guide assigned us by the author of our nature."* That we ought to do an action, is of itself a sufficient and ultimate answer to the questions, *why* we should do it?—how we are *obliged* to do it? The conviction of duty implies the soundest reason, the strongest obligation, of which our nature is susceptible.

We appear then to be using only language which is well capable of being justified, when we speak of this irresistible esteem for what is right, this conviction of a rule of action extending beyond the gratification of our irreflective impulses, as an impress stamped upon the human mind by the Deity himself; a trace of His nature; an indication of His will; an announcement of His purpose; a promise of His favour: and though this faculty may need to be confirmed and unfolded, instructed and assisted by other aids, it still seems to contain in itself a sufficient intimation that the highest objects of man's existence are to be attained, by means of a direct and intimate reference of his thoughts and actions to the Divine Author of his being.

Such then is the Deity to which the researches of Natural Theology point; and so far is the train of reflections in which we have engaged, from being merely speculative and barren. With the material world we cannot stop. If a superior Intelligence *have* ordered and adjusted the succession of seasons and the structure of the plants of the field, we must allow far more than this at first sight would seem to imply. We must admit still greater powers, still higher wisdom for the creation of the beasts of the forest with their faculties; and higher wisdom still and more transcendent attributes, for the creation of man. And when we reach this point, we find that it is not knowledge only, not power only, not foresight

* Butler, Serm. 3.

and beneficence alone, which we must attribute to the Maker of the World; but that we must consider him as the Author, in us, of a reverence for moral purity and rectitude; and, if the author of such emotions in us, how can we conceive of Him otherwise, than that these qualities are parts of his nature; and that he is not only wise and great, and good, incomparably beyond our highest conceptions, but also conformed in his purposes to the rule which he thus impresses upon us, that is, Holy in the highest degree which we can image to ourselves as possible.

CHAPTER II.

ON THE VASTNESS OF THE UNIVERSE.

1. The aspect of the world, even without any of the peculiar lights which science throws upon it, is fitted to give us an idea of the greatness of the power by which it is directed and governed, far exceeding any notions of power and greatness which are suggested by any other contemplation. The number of human beings who surround us—the various conditions requisite for their life, nutrition, well-being, all fulfilled;—the way in which these conditions are modified, as we pass in thought to other countries, by climate, temperament, habit;—the vast amount of the human population of the globe thus made up;—yet man himself but one among almost endless tribes of animals;—the forest, the field, the desert, the air, the ocean, all teeming with creatures whose bodily wants are as carefully provided for as his;—the sun, the clouds, the winds, all attending, as it were, on these organized beings;—a host of beneficent energies, unwearied by time and succession, pervading every corner of the earth;—this spectacle cannot but give the contemplator a lofty and magnificent conception of the Author of so vast a work, of the Ruler of so wide and rich an empire, of the Provider for so many and varied wants, the Director and Adjuster of such complex and jarring interests.

But when we take a more exact view of this spectacle, and aid our vision by the discoveries which have been made of the structure and extent of the universe, the impression is incalculably increased.

The number and variety of animals, the exquisite skill displayed in their structure, the comprehensive and profound relations by which they are connected, far exceed anything which we could in any degree have imagined. But the view of the universe expands

also on another side. The earth, the globular body thus covered with life, is not the only globe in the universe. There are, circling about our own sun, six others, so far as we can judge, perfectly analogous in their nature: besides our moon and other bodies analogous to it. No one can resist the temptation to conjecture, that these globes, some of them much larger than our own, are not dead and barren;—that they are, like ours, occupied with organization, life, intelligence. To conjecture is all that we can do, yet even by the perception of such a possibility, our view of the kingdom of nature is enlarged and elevated. The outermost of the planetary globes of which we have spoken is so far from the sun, that the central luminary must appear to the inhabitants of that planet, if any there are, no larger than Venus does to us; and the length of their year will be 82 of ours.

But astronomy carries us still onwards. It teaches us that, with the exception of the planets already mentioned, the stars which we see have no immediate relation to our system. The obvious supposition is that they are of the nature and order of our sun: the minuteness of their apparent magnitude agrees, on this supposition, with the enormous and almost inconceivable distance which, from all the measurements of astronomers, we are led to attribute to them. If then these are suns, they may, like our sun, have planets revolving round them; and these may, like our planet, be the seats of vegetable and animal and rational life:—we may thus have in the universe worlds, no one knows how many, no one can guess how varied:—but however many, however varied, they are still but so many provinces in the same empire, subject to common rules, governed by a common power.

But the stars which we see with the naked eye are but a very small portion of those which the telescope unveils to us. The most imperfect telescope will discover some that are invisible without it; the very best instrument perhaps does not show us the most remote. The number which crowd some parts of the heavens is truly marvellous. Dr. Herschel calculated that a portion of the milky way, about 10 degrees long and 2½ broad, contained 258,000. In a sky so occupied the moon would eclipse 2000 of such stars at once.

We learn too from the telescope that even in this province the variety of nature is not exhausted. Not only do the stars differ in colour and appearance, but some of them grow periodically fainter and brighter, as if they were dark on one side, and revolved on their axis. In other cases two stars appear close to each other, and in some of these cases it has been clearly established, that the two have a motion of revolution about each other; thus exhibiting an arrangement before unguessed, and giving rise, possibly, to new conditions of worlds. In other instances again, the telescope shows, not luminous points, but extended masses of dilute light, like

bright clouds, hence called *nebulæ*. Some have supposed (as we have noticed in the last book) that such nebulæ by further condensation might become suns; but for such opinions we have nothing but conjecture. Some stars again have undergone permanent changes, or have absolutely disappeared, as the celebrated star of 1572, in the constellation Cassiopea.

If we take the whole range of created objects in our own system, from the sun down to the smallest animalcule, and suppose such a system, or something in some way analogous to it, to be repeated for each of the millions of stars thus revealed to us, we have a representation of the material part of the universe, according to a view which many minds receive as a probable one; and referring this aggregate of systems to the Author of the universe, as in our own system we have found ourselves led to do, we have thus an estimate of the extent to which his creative energy would thus appear to have been exercised in the material world.

If we consider further the endless and admirable contrivances and adaptations which philosophers and observers have discovered in every portion of our own system, every new step of our knowledge showing us something new in this respect; and if we combine this consideration with the thought how small a portion of the universe our knowledge includes, we shall, without being able at all to discern the extent of the skill and wisdom thus displayed, see something of the character of the design, and of the copiousness and ampleness of the means which the scheme of the world exhibits. And when we see that the tendency of all the arrangements which we can comprehend is to support the existence, to develope the faculties, to promote the well-being of these countless species of creatures; we shall have some impression of the beneficence and love of the Creator, as manifested in the physical government of his creation.

2. It is extremely difficult to devise any means of bringing before a common apprehension the scale on which the universe is constructed, the enormous proportion which the larger dimensions bear to the smaller, and the amazing number of steps from large to smaller, or from small to larger, which the consideration of it offers. The following comparative representations may serve to give the reader to whom the subject is new some idea of these steps.

If we suppose the earth to be represented by a globe a foot in diameter, the distance of the sun from the earth will be about two miles; the diameter of the sun, on the same supposition, will be something above one hundred feet, and consequently his bulk such as might be made up of two hemispheres, each about the size of the dome of St. Paul's. The moon will be thirty feet from us, and her diameter three inches, about that of a cricket ball. Thus the sun would much more than occupy all the space within the moon's orbit. On the same scale, Jupiter would be above ten miles from

the sun, and Uranus forty. We see then how thinly scattered through space are the heavenly bodies. The fixed stars would be at an unknown distance, but, probably, if all distances were thus diminished, no star would be nearer to such a one-foot earth, than the moon now is to us.

On such a terrestrial globe the highest mountains would be about 1-80th of an inch high, and consequently only just distinguishable. We may imagine therefore how imperceptible would be the largest animals. The whole organized covering of such a globe would be quite undiscoverable by the eye, except perhaps by colour, like the bloom on a plum.

In order to restore this earth and its inhabitants to their true dimensions, we must magnify them forty millions of times; and to preserve the proportions, we must increase equally the distances of the sun and of the stars from us. They seem thus to pass off into infinity; yet each of them thus removed, has its system of mechanical and perhaps of organic processes going on upon its surface.

But the arrangements of organic life which we can see with the naked eye are few, compared with those which the microscope detects. We know that we may magnify objects thousands of times, and still discover fresh complexities of structure; if we suppose, therefore, that we increase every particle of matter in our universe in such a proportion, in length, breadth, and thickness, we may conceive that we tend thus to bring before our apprehension a true estimate of the quantity of organized adaptations which are ready to testify the extent of the Creator's power.

3. The other numerical quantities which we have to consider in the phenomena of the universe are on as gigantic a scale as the distances and sizes. By the rotation of the earth on its axis, the parts of the equator move at the rate of a thousand miles an hour, and the portions of the earth's surface which are in our latitude, at about six hundred. The former velocity is nearly that with which a cannon ball is discharged from the mouth of a gun; but, large as it is, it is inconsiderable compared with the velocity of the earth in its orbit about the sun. This latter velocity is sixty-five times the former. By the rotatory motion of the earth, a point on its surface is carried sometimes forwards and sometimes backwards with regard to the annual progression; but in consequence of the great predominance of the latter velocity in amount, the former scarcely affects it either way. And even the latter velocity is inconsiderable compared with that of light; which comparison, however, we shall not make; since, according to the theory we have considered as most probable, the motion of light is not a transfer of matter but of motion from one part of space to another.

The extent of the scale of density of different substances has already been mentioned; gold is twenty times as heavy as water; air is eight hundred and thirty times lighter, steam 1-8000 times lighter

than water; the luminiferous ether is incomparably rarer than steam: and this is true of the matter of light, whether we adopt the undulatory theory or any other.

4. The above statements are vast in amount, and almost oppressive to our faculties. They belong to the measurement of the powers which are exerted in the universe, and of the spaces through which their efficacy reaches (for the most distant bodies are probably connected both by gravity and light.) But these estimates cannot be said so much to give us any notion of the powers of the Deity, as to correct the errors we should fall into by supposing his powers at all to resemble ours:—by supposing that numbers, and spaces, and forces, and combinations, which would overwhelm us, are any obstacle to the arrangements which his plan requires. We can easily understand that to an intelligence surpassing ours in degree only, that may be easy which is impossible to us. The child who cannot count beyond four, the savage who has no name for any number above five, cannot comprehend the possibility of dealing with thousands and millions: yet a little additional developement of the intellect makes such numbers manageable and conceivable. The difficulty which appears to reside in numbers and magnitudes and stages of subordination, is one produced by judging from ourselves—by measuring with our own sounding line; when that reaches no bottom, the ocean appears unfathomable. Yet in fact, how is a hundred millions of miles a *great* distance? how is a hundred millions of times a *great* ratio? Not in itself: this *greatness* is no quality of the numbers which can be proved like their mathematical properties; on the contrary, all that absolutely belongs to number, space, and ratio, must, we know demonstrably, be equally true of the largest and the smallest. It is clear that the *greatness* of these expressions of measure has reference to *our* faculties only. Our astonishment and embarrassment take for granted the limits of our own nature. We have a tendency to treat a difference of degree and of addition, as if it were a difference of kind and of transformation. The existence of the attributes, design, power, goodness, is a matter depending on obvious grounds: about these qualities there can be no mistake: if we can know anything, we can know these attributes when we see them. But the extent, the limits of such attributes must be determined by their effects; our knowledge of their limits by what we see of the effects. Nor is any extent, any amount of power and goodness improbable before hand: we know that these must be great, we cannot tell how great. We should not expect beforehand to find them bounded; and therefore when the boundless prospect opens before us, we may be bewildered, but we have no reason to be shaken in our conviction of the reality of the cause from which their effects proceed: we may feel ourselves incapable of following the train of thought, and may stop,

but we have no rational motive for quitting the point which we have thus attained in tracing the Divine Perfections.

On the contrary, those magnitudes and proportions which leave our powers of conception far behind;—that ever-expanding view which is brought before us, of the scale and mechanism, the riches and magnificence, the population and activity of the universe;—may reasonably serve, not to disturb, but enlarge and elevate our conceptions of the Maker and Master of all; to feed an ever-growing admiration of His wonderful nature; and to excite a desire to be able to contemplate more steadily and conceive less inadequately the scheme of his government and the operation of his power.

CHAPTER III.

ON MAN'S PLACE IN THE UNIVERSE.

The mere aspect of the starry heavens, without taking into account the view of them to which science introduces us, tends strongly to force upon man the impression of his own insignificance. The vault of the sky arched at a vast and unknown distance over our heads; the stars, apparently infinite in number, each keeping its appointed place and course, and seeming to belong to a wide system of things which has no relation to the earth; while man is but one among many millions of the earth's inhabitants;—all this makes the contemplative spectator feel how exceedingly small a portion of the universe he is; how little he must be, in the eyes of an intelligence which can embrace the whole. Every person, in every age and country, will recognise as irresistibly natural the train of thought expressed by the Hebrew psalmist: "when I consider the heavens the work of thy hands—the moon and the stars which thou hast ordained—Lord what is man that thou art mindful of him, or the son of man that thou regardest him?"

If this be the feeling of the untaught person, when he contemplates the aspect of the skies, such as they offer themselves to a casual and unassisted glance, the impression must needs be incalculably augmented, when we look at the universe with the aid of astronomical discovery and theory. We then find, that a few of the shining points which we see scattered on the face of the sky in such profusion, appear to be of the same nature as the earth, and may perhaps, as analogy would suggest, be like the earth, the habitations of organized beings;—that the rest of "the host of heaven" may, by a like analogy, be conjectured to be the centres of similar systems of revolving worlds;—that the vision of man has gone travelling on-

wards, to an extent never anticipated, through this multitude of systems, and that while myriads of new centres start up at every advance, he appears as yet not to have received any intimation of a limit. Every person probably feels, at first, lost, confounded, overwhelmed, with the vastness of this spectacle, and seems to himself, as it were, annihilated by the magnitude and multitude of the objects which thus compose the universe. The distance between him and the Creator of the world appears to be increased beyond measure by this disclosure. It seems as if a single individual could have no chance and no claim for the regard of the Ruler of the whole.

The mode in which the belief of God's government of the physical world is important and interesting to man, is, as has already been said, through the connexion which this belief has with the conviction of God's government of the moral world; this latter government being, from its nature, one which has a personal relation to each individual, his actions and thoughts. It will, therefore, illustrate our subject to show that this impression of the difficulty of a personal superintendence and government, exercised by the Maker of the world over each of his rational and free creatures, is founded upon illusory views; and that on an attentive and philosophical examination of the subject, such a government is in accordance with all that we can discover of the scheme and the scale of the universe.

1. We may, in the first place, repeat the observation made in the last chapter, on the confusion which sometimes arises in our minds, and makes us consider the number of the objects of the Divine care as a difficulty in the way of its exercise. If we can conceive this care employed on a million persons, on the population of a kingdom, of a city, of a street, there is no real difficulty in supposing it extended to every planet in the solar system, admitting each to be peopled as ours is; nor to every part of the universe, supposing each star the centre of such a system. *Numbers* are nothing in themselves; and when we reject the known, but unessential limits of our own faculties, it is quite as allowable to suppose a million millions of earths, as one, to be under the moral government of God.

2. In the next place we may remark, not only that no reason can be assigned why the Divine care should not extend to a much greater number of individuals than we at first imagine, but that in fact we know that it *does* so extend. It has been well observed, that about the same time when the invention of the telescope showed us that there might be myriads of other worlds claiming the Creator's care; the invention of the microscope proved to us that there were in our own world myriads of creatures, before unknown, which this care was preserving. While one discovery seemed to remove the Divine Providence further from us, the other gave us most striking examples that it was far more active in our neighbourhood than we had supposed: while the first extended the boundaries of God's known kingdom, the second made its known administration more

minute and careful. It appeared that in the leaf and in the bud, in solids and in fluids, animals existed hitherto unsuspected; the apparently dead masses and blank spaces of the world were found to swarm with life. And yet, of the animals thus revealed, all, though unknown to us before, had never been forgotten by Providence. Their structure, their vessels and limbs, their adaptation to their situation, their food and habitations, were regulated in as beautiful and complete a manner as those of the largest and apparently most favoured animals. The smallest insects are as exactly finished, often as gaily ornamented, as the most graceful beasts or the birds of brightest plumage. And when we seem to go out of the domain of the complex animal structure with which we are familiar, and come to animals of apparently more scanty faculties, and less developed powers of enjoyment and action, we still find that their faculties and their senses are in exact harmony with their situation and circumstances; that the wants which they have are provided for, and the powers which they possess called into activity. So that Müller, the patient and accurate observer of the smallest and most obscure microscopical animalcula, declares that all classes alike, those which have manifest organs, and those which have not, offer a vast quantity of new and striking views of the animal economy; every step of our discoveries leading us to admire the design and care of the Creator.* We find, therefore, that the Divine Providence is, in fact, capable of extending itself adequately to an immense succession of tribes of beings, surpassing what we can image or could previously have anticipated; and thus we may feel secure, so far as analogy can secure us, that the mere multitude of created objects cannot remove us from the government and superintendence of the Creator.

3. We may observe further, that, vast as are the parts and proportions of the universe, we still appear to be able to perceive that it is *finite;* the subordination of magnitudes and numbers and classes appears to have its limits. Thus, for anything which we can discover, the sun is the largest body in the universe; and at any rate, bodies of the order of the sun are the largest of which we have any evidence: we know of no substance denser than gold, and it is improbable that one denser, or at least much denser, should ever be detected: the largest animals which exist in the sea and on the earth are almost certainly known to us. We may venture also to say, that the smallest animals which possess in their structure a clear analogy with larger ones, have been already seen. Many of the animals which the microscope detects, are as complete and complex in their organization as those of larger size: but beyond a certain point, they appear, as they become more minute, to be reduced to a homogeneity and simplicity of composition which almost excludes them from the domain of animal life. The smallest microscopical

* Müller, Infusoria, Preface.

objects which can be supposed to be organic, are points,* or gelatinous globules,† or threads,‡ in which no distinct organs, interior or exterior, can be discovered. These, it is clear, cannot be considered as indicating an indefinite progression of animal life in a descending scale of minuteness. We can, mathematically speaking, conceive one of these animals as perfect and complicated in its structure as an elephant or an eagle, but we do not find it so in nature. It appears, on the contrary, in these objects, as if we were, at a certain point of magnitude, reaching the boundaries of the animal world. We need not here consider the hypotheses and opinions to which these ambiguous objects have given rise; but, without any theory, they tend to show that the subordination of organic life is finite on the side of the little as well as of the great.

Some persons might, perhaps, imagine that a ground for believing the smallness of organized beings to be limited, might be found in what we know of the constitution of matter. If solids and fluids consist of particles of a definite, though exceeding smallness, which cannot further be divided or diminished, it is manifest that we have, in the smallness of these particles, a limit to the possible size of the vessels and organs of animals. The fluids which are secreted, and which circulate in the body of a mite, must needs consist of a vast number of particles, or they would not be fluids: and an animal might be so much smaller than a mite, that its tubes could not contain a sufficient collection of the atoms of matter, to carry on its functions. We should, therefore, of necessity reach a limit of minuteness in organic life, if we would demonstrate that matter is composed of such indivisible atoms. We shall not, however, build anything on this argument; because, though the *atomic theory* is sometimes said to be proved, what is proved is, that chemical and other effects take place as if they were the aggregate of the effects of certain particles of elements, the *proportions* of which particles are fixed and definite; but that any limit can be assigned to the smallness of these particles, has never yet been made out. We prefer, therefore, to rest the proof of the finite extent of animal life, as to size, on the microscopical observations previously referred to.

Probably we cannot yet be said to have reached the limit of the universe with the power of our telescopes; that is, it does not appear that telescopes have yet been used, so powerful in exhibiting small stars, that we can assume that more powerful instruments would not discover new stars. Whether or not, however, this degree of perfection has been reached, we have no proof that it does not exist: if it were once obtained we should have, with some approximation, the limit of the universe as to the number of worlds, as we have already endeavoured to show we have obtained the limits with regard to the largeness and smallness of the inhabitants of our own world.

* *Monas.* Muller. Cuvier. † *Volvox.* ‡ *Vibrio.* Muller. Cuvier.

In like manner, although the discovery of new species in some of the kingdoms of nature has gone on recently with enormous rapidity, and to an immense extent;—for instance in botany, where the species known in the time of Linnæus were about 10,000, and are now probably 50,000;—there can be no doubt that the number of species and genera is really limited; and though a great extension of our knowledge is required to reach these limits, it is our ignorance merely, and not their non-existence, which removes them from us.

In the same way it would appear that the universe, so far as it is an object of our knowledge, is finite in other respects also. Now when we have once attained this conviction, all the oppressive apprehension of being overlooked in the government of the universe has no longer any rational source. For in the superintendence of a finite system of things, what is there which can appear difficult or overwhelming to a Being such as we must, from what we know, conceive the Creator to be? Difficulties arising from space, number, gradation, are such as we can conceive *ourselves* capable of overcoming, merely by an extension of our present faculties. Is it not then easy to imagine that such difficulties must vanish before Him who made us and our faculties? Let it be considered how enormous a proportion the largest work of man bears to the smallest;—the great pyramid to the point of a needle. This comparison does not overwhelm us, because we know that man has made both. Yet the difference between this proportion and that of the sun to the claw of a mite, does not at all correspond to the difference which we must suppose to obtain between the Creator and the creature. It appears then that, if the first flash of that view of the universe which science reveals to us, does sometimes dazzle and bewilder men, a more attentive examination of the prospect, by the light we thus obtain, shows us how unfounded is the despair of our being the objects of Divine Providence, how absurd the persuasion that we have discovered the universe to be too large for its ruler.

4. Another ground of satisfactory reflexion, having the same tendency, is to be found in the admirable order and consistency, the subordination and proportion of parts, which we find to prevail in the universe, as far as our discoveries reach. We have, it may be, a multitude almost innumerable of worlds, but no symptom of crowding, of confusion, of interference. All such defects are avoided by the manner in which these worlds are distributed into systems;—these systems, each occupying a vast space, but yet disposed at distances before which their own dimensions shrink into insignificance;—all governed by one law, yet this law so concentrating its operation on each system, that each proceeds as if there were no other, and so regulating its own effects that perpetual change produces permanent uniformity. This is the kind of harmonious relation which we perceive in that part of the universe, the mechanical part namely, the laws of which are best known to us. In other pro-

vinces, where our knowledge is more imperfect, we can see glimpses of a similar vastness of combination, producing, by its very nature, completeness of detail. Any analogy by which we can extend such views to the moral world, must be of a very wide and indefinite kind; yet the contemplation of this admirable relation of the arrangements of the physical creation, and the perfect working of their laws, is well calculated to give us confidence in a similar beauty and perfection in the arrangements by which our moral relations are directed, our higher powers and hopes unfolded. We may readily believe that there is, in this part of the creation also, an order, a subordination of some relations to others, which may remove all difficulty arising from the vast multitude of moral agents and actions, and make it possible that the superintendence of the moral world shall be directed with as exact a tendency to moral good, as that by which the government of the physical world is directed to physical good.

We may perhaps see glimpses of such an order, in the arrangements by which our highest and most important duties depend upon our relation to a small circle of persons immediately around us: and again, in the manner in which our acting well or ill results from the operation of a few principles within us; as our conscience, our desire of moral excellence, and of the favour of God. We can hardly consider such principles otherwise than as intended to occupy their proper place in the system by which man's destination is to be determined; and thus, as among the means of the government and superintendence of God in the moral world.

That there must be an order and a system to which such regulative principles belong, the whole analogy of creation compels us to believe. It would be strange indeed, if, while the mechanical world, the system of inert matter, is so arranged that we cannot contemplate its order without an elevated intellectual pleasure;—while organized life has no faculties without their proper scope, no tendencies without their appointed object;—the rational faculties and moral tendencies of man should belong to no systematic order, should operate with no corresponding purpose: that, while the perception of sweet and bitter has its acknowledged and unmistakeable uses, the universal perception of right and wrong, the unconquerable belief of the merit of certain feelings and actions, the craving alike after moral advancement and after the means of attaining it, should exist only to delude, perplex, and disappoint man. No one, with his contemplations calmed and filled and harmonized by the view of the known constitution of the universe, its machinery "wheeling unshaken" in the farthest skies and in the darkest cavern, its vital spirit breathing alike effectively in the veins of the philosopher and the worm;—no one, under the influence of such a train of contemplations, can possibly admit into his mind a persuasion which makes the moral part of our nature a collection of inconsistent and

futile impressions, of idle dreams and warring opinions, each having the same claims to our acceptance. Wide as is the distance between the material and the moral world; shadowy as all reasonings necessarily are which attempt to carry the inferences of one into the other; elevated above the region of matter as all the principles and grounds of truth must be, which belong to our responsibilities and hopes; still the astronomical and natural philosopher can hardly fail to draw from their studies an imperturbable conviction that our moral nature cannot correspond to those representations according to which it has no law, coherency, or object. The mere natural reasoner may, or must, stop far short of all that it is his highest interest to know, his first duty to pursue; but even he, if he take any elevated and comprehensive views of his own subject, must escape from the opinions, as unphilosophical as they are comfortless, which would expel from our view of the world all reference to duty and moral good, all reliance on the most universal grounds of trust and hope.

Men's belief of their duty, and of the reasons for practising it, connected as it is with the conviction of a personal relation to their Maker, and of His power of superintendence and reward, is as manifest a fact in the moral, as any that can be pointed out is in the natural world. By the mere analogy which has been intimated, therefore, we cannot but conceive that this fact belongs in some manner or other to the order of the moral world, and of its government.

When any one acknowledges a moral governor of the world; perceives that domestic and social relations are perpetually operating and seem intended to operate, to retain and direct men in the path of duty; and feels that the voice of conscience, the peace of heart which results from a course of virtue, and the consolations of devotion, are ever ready to assume their office as our guides and aids in the conduct of all our actions;—he will probably be willing to acknowledge also that the means of moral government are not wanting, and will no longer be oppressed or disturbed by the apprehension that the superintendence of the world may be too difficult for its Ruler, and that any of His subjects and servants may be overlooked. He will no more fear that the moral than that the physical laws of God's creation should be forgotten in any particular case: and as he knows that every sparrow which falls to the ground contains in its structure innumerable marks of the Divine care and kindness, he will be persuaded that every individual, however apparently humble and insignificant, will have his moral being dealt with according to the laws of God's wisdom and love; will be enlightened, supported, and raised, if he use the appointed means which God's administration of the world of moral light and good offers to his use.

CHAPTER IV.

ON THE IMPRESSION PRODUCED BY THE CONTEMPLATION OF THE LAWS OF NATURE; OR, ON THE CONVICTION THAT LAW IMPLIES MIND.

THE various trains of thought and reasoning which lead men from a consideration of the natural world to the conviction of the existence, the power, the providence of God, do not require, for the most part, any long or laboured deduction, to give them their effect on the mind. On the contrary, they have, in every age and country, produced their impression on multitudes who have not instituted any formal reasonings upon the subject, and probably upon many who have not put their conclusions in the shape of any express propositions. The persuasion of a superior intelligence and will, which manifests itself in every part of the material world, is, as is well known, so widely diffused and deeply infixed, as to have made it a question among speculative men whether the notion of such a power is not universal and innate. It is our business to show only how plainly and how universally such a belief results from the study of the appearances about us. That in many nations, in many periods, this persuasion has been mixed up with much that was erroneous and perverse in the opinions of the intellect or the fictions of the fancy, does not weaken the force of such consent. The belief of a supernatural and presiding power runs through all these errors: and while the perversions are manifestly the work of caprice and illusion, and vanish at the first ray of sober inquiry, the belief itself is substantial and consistent, and grows in strength upon every new examination. It was the firmness and solidity of the conviction of *something* Divine which gave a hold and permanence to the figments of so many false divinities. And those who have traced the progress of human thought on other subjects, will not think it strange, that while the fundamental persuasion of a Deity was thus irremoveably seated in the human mind, the developement of this conception into a consistent, pure, and steadfast belief in one Almighty and Holy Father and God, should be long missed, or never attained, by the struggle of the human faculties; should require long reflexion to mature it, and the aid of revelation to establish it in the world.

The view of the universe which we have principally had occasion to present to the reader, is that in which we consider its appearances as reducible to certain fixed and general laws. Availing ourselves of some of the lights which modern science supplies, we

have endeavoured to show that the adaptation of such laws to each other, and their fitness to promote the harmonious and beneficial course of the world, may be traced, wherever we can discover the laws themselves; and that the conceptions of the Divine Power, Goodness and Superintendence which we thus form, agree in a remarkable manner with the views of the Supreme Being, to which reason, enlightened by the divine revelation, has led.

But we conceive that the general impressions of mankind would go further than a mere assent to the argument as we have thus stated it. To most persons it appears that the mere existence of a law connecting and governing any class of phenomena, implies a presiding intelligence which has preconceived and established the law. When events are regulated by precise rules of time and space, of number and measure, men conceive these rules to be the evidence of thought and mind, even without discovering in the rules any peculiar adaptations, or without supposing their purpose to be known.

The origin and the validity of such an impression on the human mind may appear to some matters of abstruse and doubtful speculation: yet the tendency to such a belief prevails strongly and widely, both among the common class of minds whose thoughts are casually and unsystematically turned to such subjects, and among philosophers to whom laws of nature are habitual subjects of contemplation. We conceive therefore that such a tendency may deserve to be briefly illustrated; and we trust also that some attention to this point may be of service in throwing light upon the true relation of the study of nature to the belief in God.

1. A very slight attention shows us how readily order and regularity suggest to a common apprehension the operation of a calm and untroubled intelligence presiding over the course of events. Thus the materialist poet, in accounting for the belief in the Gods, though he does not share it, cannot deny the habitual effect of this manifestation.

> Præterea cœli rationes *ordine certo*
> Et *varia* annorum cernebant *tempora* vorti;
> Nec poterant quibus id fieret cognoscere causis.
> Ergo perfugium sibi habebant omnia Divis
> Tradere et illorum nutu facere omnia flecti.
>
> LUCRET. V. 1182.

> They saw the skies in constant order run,
> The varied seasons and the circling sun,
> Apparent rule, with unapparent cause,
> And thus they sought in Gods the source of laws.

The same feeling may be traced in the early mythology of a large portion of the globe. We might easily, taking advantage of the labours of learned men, exemplify this in the case of the oriental na-

tions, of Greece, and of many other countries. Nor does there appear much difficulty in pointing out the error of those who have maintained that all religion had its *origin* in the worship of the stars and the elements; and who have insinuated that all such impressions are unfounded, inasmuch as these are certainly not right objects of human worship. The religious feeling, the conviction of a supernatural power, of an intelligence connecting and directing the phenomena of the world, had not its *origin* in the worship of sun, or stars, or elements; but was itself the necessary though unexpressed foundation of all worship, and all forms of false, as well as true, religion. The contemplation of the earth and heavens called into action this religious tendency in man; and to say that the worship of the material world formed or suggested this religious feeling, is to invert the order of possible things in the most unphilosophical manner. Idolatry is not the source of the belief in God, but is a compound of the persuasion of a supernatural government, with certain extravagant and baseless conceptions as to the manner in which this government is exercised.

We will quote a passage from an author who has illustrated at considerable length the hypothesis that all religious belief is derived from the worship of the elements.

"Light, and darkness is perpetual contrast; the succession of days and nights, the periodical order of the seasons; the career of the brilliant luminary which regulates their course; that of the moon his sister and rival; night, and the innumerable fires which she lights in the blue vault of heaven; the revolutions of the stars, which exhibit them for a longer or a shorter period above our horizon; the constancy of this period in the fixed stars, its variety in the wandering stars, the planets; their direct and retrograde course, their momentary rest; the phases of the moon waxing, full, waning, divested of all light; the progressive motion of the sun upwards, downwards; the successive order of the rising and setting of the fixed stars which mark the different points of the course of the sun, while the various aspects which the earth itself assumes mark, here below also, the same periods of the sun's annual motion; . . . all these different pictures, displayed before the eyes of man, formed the great and magnificent spectacle by which I suppose him surrounded at the moment when *he is about to create his gods.*"*

What is this (divested of its wanton levity of expression) but to say, that when man has so far traced the course of nature as to be irresistibly impressed with the existence of order, law, variety in constancy, and fixity in change; of relations of form and space, duration and succession, cause and consequence, among the objects which surround him; there springs up in his breast, unbidden and

* Dupuis. Origine des Cultes.

irresistibly, the thought of superintending intelligence, of a mind which comprehended from the first and completely that which he late and partially comes to know? The worship of earth and sky, of the host of heaven and the influences of nature, is not the ultimate and fundamental fact in the early history of the religious impressions of mankind. These are but derivative streams, impure and scanty, from the fountain of religious feeling which appears to be disclosed to us by the contemplation of the universe, as the seat of law and the manifestation of intellect. Time suggests to man the thought of eternity; space of infinity; law of intelligence; order of purpose; and however difficult and long a task it may be to develope these suggestions into clear convictions, these thoughts are the real parents of our natural religious belief. The only relation between true religion and the worship of the elemental world is, that the latter is the partial and gross perversion, the former the consistent and pure developement of the same original idea.

2. The connexion of the laws of the material world with an intelligence which preconceived and instituted the law, which is thus, as we perceive, so generally impressed on the common apprehension of mankind, has also struck no less those who have studied nature with a more systematic attention, and with the peculiar views which belong to science. The laws which such persons learn and study, seem, indeed, most naturally to lead to the conviction of an intelligence which originally gave to the law its form.

What we call a general law is, in truth, a form of expression including a number of facts of like kind. The facts are separate; the unity of view by which we associate them, the character of generality and of law, resides in those relations which are the object of the intellect. The law once apprehended by us, takes in our minds the place of the facts themselves, and is said to *govern* or determine them, because it determines our anticipations of what they will be. But we cannot, it would seem, conceive a law, founded on such intelligible relations, to govern and determine the facts themselves, any otherwise than by supposing also an intelligence by which these relations are contemplated, and these consequences realised. We cannot then represent to ourselves the universe governed by general laws otherwise than by conceiving an intelligent and conscious Deity, by whom these laws were originally contemplated, established, and applied.

This perhaps will appear more clear, when it is considered that the laws of which we speak are often of an abstruse and complex kind, depending upon relations of space, time, number, and other properties, which we perceive by great attention and thought. These relations are often combined so variously and curiously, that the most subtle reasonings and calculations which we can form are requisite in order to trace their results. Can such laws be conceived to be instituted without any exercise of knowledge and intelligence?

can material objects apply geometry and calculation to themselves? can the lenses of the eye, for instance, be formed and adjusted with an exact suitableness to their refractive powers, while there is in the agency which has framed them, no consciousness of the laws of light, of the course of rays, of the visible properties of things? This appears to be altogether inconceivable.

Every particle of matter possesses an almost endless train of properties, each acting according to its peculiar and fixed laws. For every atom of the same kind of matter these laws are invariably and perpetually the same, while for different kinds of matter the difference of these properties is equally constant. This constant and precise resemblance, this variation equally constant and equally regular, suggest irresistibly the conception of some cause, independent of the atoms themselves, by which their similarity and dissimilarity, the agreement and difference of their deportment under the same circumstances, have been determined. Such a view of the constitution of matter, as is observed by an eminent writer of our own time, effectually destroys the idea of its external and self-existent nature, "by giving to each of its atoms the essential characters, at once, of a *manufactured article* and a *subordinate agent*."*

That such an impression, and the consequent belief in a divine Author of the universe, by whom its laws were ordained and established, does result from the philosophical contemplation of nature, will, we trust, become still more evident by tracing the effect produced upon men's minds by the discovery of such laws and properties as those of which we have been speaking; and we shall therefore make a few observations on this subject.

CHAPTER V.

ON INDUCTIVE HABITS; OR, ON THE IMPRESSION PRODUCED ON MEN'S MINDS BY DISCOVERING LAWS OF NATURE.

The object of physical science is to discover such laws and properties as those of which we have spoken in the last chapter. In this task, undoubtedly a progress has been made on which we may well look with pleasure and admiration; yet we cannot hesitate to confess that the extent of our knowledge on such subjects bears no proportion to that of our ignorance. Of the great and comprehensive laws which rule over the widest provinces of natural phenomena, few have yet been disclosed to us. And the names of the philoso-

* Herschel on the Study of Nat. Phil. Art. 28.

phers, whose high office it has been to detect such laws, are even yet far from numerous. In looking back at the path by which science has advanced to its present position, we see the names of great discoverers shine out like luminaries, few and scattered along the line: by far the largest portion of the space is occupied by those whose comparatively humble office it was to verify, to develope, to apply the general truths which the discoverers brought to light.

It will readily be conceived that it is no easy matter, if it be possible, to analyse the process of thought by which laws of nature have thus been discovered; a process which, as we have said, has been in so few instances successfully performed. We shall not here make any attempt at such an analysis. But without this, we conceive it may be shown that the constitution and employment of the mind on which such discoveries depend, are friendly to that belief in a wise and good Creator and Governor of the world, which it has been our object to illustrate and confirm. And if it should appear that those who see further than their fellows into the bearings and dependencies of the material things and elements by which they are surrounded, have also been, in almost every case, earnest and forward in acknowledging the relation of all things to a supreme intelligence and will; we shall be fortified in our persuasion that the true scientific perception of the general constitution of the universe, and of the mode in which events are produced and connected, is fitted to lead us to the conception and belief of God.

Let us consider for a moment what takes place in the mind of a student of nature when he attains to the perception of a law previously unknown, connecting the appearances which he has studied. A mass of facts which before seemed incoherent and unmeaning, assume, on a sudden, the aspect of connexion and intelligible order. Thus, when Kepler discovered the law which connects the periodic times with the diameters of the planetary orbits; or, when Newton showed how this and all other known mathematical properties of the solar system were included in the law of universal gravitation according to the inverse square of the distance; particular circumstances which, before, were merely matter of independent record, became, from that time, indissolubly conjoined by the laws so discovered. The separate occurrences and facts, which might hitherto have seemed casual and without reason, were now seen to be all exemplifications of the same truth. The change is like that which takes place when we attempt to read a sentence written in difficult or imperfect characters. For a time the separate parts appear to be disjointed and arbitrary marks; the suggestions of possible meanings, which succeed each other in the mind, fail, as fast as they are tried, in combining or accounting for these symbols: but at last the true supposition occurs; some words are found to coincide with the meaning thus assumed; the whole line of letters appear to take definite shapes and to leap into their proper places;

and the truth of the happy conjecture seems to flash upon us from every part of the inscription.

The discovery of laws of nature, truly and satisfactorily connecting and explaining phenomena, of which, before, the connexion and causes had been unknown, displays much of a similar process, of obscurity succeeded by evidence, of effort and perplexity followed by conviction and repose. The innumerable conjectures and failures, the glimpses of light perpetually opening and as often clouded over, the unwearied perseverance and inexhaustible ingenuity exercised by Kepler in seeking for the laws which he finally discovered, are, thanks to his communicative disposition, curiously exhibited in his works, and have been narrated by his biographers; and such efforts and alterations, modified by character and circumstances, must generally precede the detection of any of the wider laws and dependencies by which the events of the universe are regulated. We may readily conceive the satisfaction and delight with which, after this perplexity and struggle, the discoverer finds himself in light and tranquillity; able to look at the province of nature which has been the subject of his study, and to read there an intelligible connexion, a sufficing reason, which no one before him had understood or apprehended.

This step so much resembles the mode in which one intelligent being understands and apprehends the conceptions of another, that we cannot be surprised if those persons in whose minds such a process has taken place, have been most ready to acknowledge the existence and operation of a superintending intelligence, whose ordinances it was their employment to study. When they had just read a sentence of the table of the laws of the universe, they could not doubt whether it had had a legislator. When they had decyphered there a comprehensive and substantial truth, they could not believe that the letters had been thrown together by chance. They could not but readily acknowledge that what their faculties had enabled them to read, must have been written by some higher and profounder mind. And accordingly, we conceive it will be found, on examining the works of those to whom we owe our knowledge of the laws of nature, and especially of the wider and more comprehensive laws, that such persons have been strongly and habitually impressed with the persuasion of a Divine Purpose and Power which had regulated the events which they had attended to, and ordained the laws which they had detected.

To those who have pursued science without reaching the rank of discoverers;—who have possessed a derivative knowledge of the laws of nature which others had disclosed, and have employed themselves in tracing the consequences of such laws, and systematising the body of truth thus produced, the above description does not apply; and we have not therefore in these cases the same ground for anticipating the same frame of mind. If among men of

science of this class, the persuasion of a supreme Intelligence has at some periods been less vivid and less universal, than in that higher class of which we have before spoken, the fact, so far as it has existed, may perhaps be in some degree accounted for. But whether the view which we have to give of the mental peculiarities of men whose science is of this derivative kind be well founded, and whether the account we have above offered of that which takes place in the minds of original discoverers of laws in scientific researches be true, or not, it will probably be considered a matter of some interest to point out historically that in fact, such discoverers have been peculiarly in the habit of considering the world as the work of God. This we shall now proceed to do.

As we have already said, the names of *great* discoverers are not very numerous. The sciences which we may look upon as having reached or at least approached their complete and finished form, are Mechanics, Hydrostatics, and Physical Astronomy. Galileo is the father of modern Mechanics; Copernicus, Kepler, and Newton are the great names which mark the progress of Astronomy. Hydrostatics shared in a great measure the fortunes of the related science of Mechanics; Boyle and Pascal were the persons mainly active in developing its more peculiar principles. The other branches of knowledge which belong to natural philosophy, as Chemistry and Meteorology, are as yet imperfect, and perhaps infant sciences; and it would be rash to presume to select, in them, names of equal pre-eminence with those above-mentioned: but it may not be difficult to show, with sufficient evidence, that the effect of science upon the authors of science is, in these subjects as in the former ones, far other than to alienate their minds from religious trains of thought, and a habit of considering the world as the work of God.

We shall not dwell much on the first of the above-mentioned great names, Galileo; for his scientific merit consisted rather in adopting the sound philosophy of others, as in the case of the Copernican system, and in combating prevalent errors, as in the case of the Aristotelian doctrines concerning motion, than in any marked and prominent discovery of new principles. Moreover the mechanical laws which he had a share in bringing to light, depending as they did, rather on detached experiments and transient facts, than on observation of the general course of the universe, could not so clearly suggest any reflexion on the government of the world at that period, as they did afterwards when Newton showed their bearing on the cosmical system. Yet Galileo, as a man of philosophical and inventive mind, who produced a great effect on the progress of physical knowledge, is a person whose opinions must naturally interest us, engaged in our present course of reasoning. There is in his writings little which bears upon religious views, as there is in the nature of his works little to lead him to such subjects.

Yet strong expressions of piety are not wanting, both in his letters, and in his published treatises. The persecution which he underwent, on account of his writings in favour of the Copernican system, was grounded, not on his opposition to the general truths of natural religion, which is our main concern at present, nor even on any supposed rejection of any articles of Christian faith, but on the alleged discrepancy between his adopted astronomical views and the declarations of scripture. Some of his remarks may interest the reader.

In his third dialogue on the Copernican system he has occasion to speak of the opinion which holds all parts of the world to be framed for man's use alone: and to this he says, "I would that we should not so shorten the arm of God in the government of human affairs; but that we should rest in this, that we are certain that God and nature are so occupied in the government of human affairs, that they could not more attend to us if they were charged with the care of the human race alone." In the same spirit, when some objected to the asserted smallness of the Medicean stars, or satellites of Jupiter, and urged this as a reason why they were unworthy the regard of philosophers, he replied that they are the works of God's power, the objects of His care, and therefore may well be considered as sublime subjects for man's study.

In the Dialogues on Mechanics, there occur those observations concerning the use of the air-bladder in fishes, and concerning the adaptation of the size of animals to the strength of the materials of which they are framed, which have often since been adopted by writers on the wisdom of Providence. The last of the dialogues on the system of the world is closed by a religious reflection, put in the mouth of the interlocutor who usually expresses Galileo's own opinions. "While it is permitted us to speculate concerning the constitution of the world, we are also taught (perhaps in order that the activity of the human mind may not pause or languish) that our powers do not enable us to comprehend the works of His hands. May success therefore attend this intellectual exercise, thus permitted and appointed for us; by which we recognise and admire the greatness of God the more, in proportion as we find ourselves the less able to penetrate the profound abysses of his wisdom." And that this train of thought was habitual to the philosopher we have abundant evidence in many other parts of his writings. He had already said in the same dialogue, "Nature (or God, as he elsewhere speaks) employs means in an admirable and inconceivable manner; admirable, that is, and inconceivable to us, but not to her, who brings about with consummate facility and simplicity things which affect our intellect with infinite astonishment. That which is to us most difficult to understand is to her most easy to execute."

The establishment of the Copernican and Newtonian views of the motions of the solar system and their causes, were probably

the occasions on which religious but unphilosophical men entertained the strongest apprehensions that the belief in the government of God may be weakened when we thus "thrust some mechanic cause into his place." It is therefore fortunate that we can show, not only that this ought not to occur, from the reason of the thing, but also that in fact the persons who are the leading characters in the progress of these opinions were men of clear and fervent piety.

In the case of Copernicus himself it does not appear that, originally, any apprehensions were entertained of any dangerous discrepancy between his doctrines and the truths of religion, either natural or revealed. The work which contains these memorable discoveries was addressed to Pope Paul III., the head, at that time, (1543) of the religious world; and was published, as the author states in the preface, at the urgent entreaty of friends, one of whom was a cardinal, and another a bishop.* "I know," he says, "that the thoughts of a philosopher are far removed from the judgment of the vulgar; since it is his study to search out truth in all things, as far as that is permitted by God to human reason." And though the doctrines are for the most part stated as portions of a mathematical calculation, the explanation of the arrangement by which the sun is placed in the centre of the system is accompanied by a natural reflexion of a religious cast; "Who in this fair temple would place this lamp in any other or better place than there whence it may illuminate the whole? We find then under this ordination an admirable symmetry of the world, and a certain harmonious connexion of the motion and magnitude of the orbs, such as in any other way cannot be found. Thus the progressions and regressions of the planets all arise from the same cause, the motion of the earth. And that no such movements are seen in the fixed stars, argues their immense distance from us, which causes the apparent magnitude of the earth's annual course to become evanescent. So great, in short, is this divine fabric of the great and good God;"† "this best and most regular artificer of the universe," as he elsewhere speaks.

Kepler was the person, who by further studying "the connexion of the motions and magnitude of the orbs," to which Copernicus had thus drawn the attention of astronomers, detected the laws of this connexion, and prepared the way for the discovery, by Newton, of the mechanical laws and causes of such motions. Kepler was a man of strong and lively piety; and the exhortation which he addresses to his reader before entering on the exposition of some of

* Amici me cunctantem atque etiam reluctantem, retraxerunt, inter quos primus fuit Nicolaus Schonbergius, Cardinalis Capuanus, in omni genere literatum celebris; proximus ille vir mei amantissimus Tidemannus Gisius, episcopus Culmensis, sacrarum ut est et omnium bonarum literarum studiosissimus.—*De Revolutionibus. Præf. ad Paulum III.*

† Lib. i. cx.

his discoveries, may be quoted not only for its earnestness but its reasonableness also. "I beseech my reader, that not unmindful of the divine goodness bestowed on man, he do with me praise and celebrate the wisdom and greatness of the Creator, which I open to him from a more inward explication of the form of the world, from a searching of causes, from a detection of the errors of vision: and that thus, not only in the firmness and stability of the earth he perceive with gratitude the preservation of all living things in nature as the gift of God, but also that in its motion, so recondite, so admirable, he acknowledge the wisdom of the Creator. But him who is too dull to receive this science, or too weak to believe the Copernican system without harm to his piety, him, I say, I advise that, leaving the school of astronomy, and condemning, if he please, any doctrines of the philosophers, he follow his own path, and desist from this wandering through the universe, and lifting up his natural eyes, with which alone he can see, pour himself out from his own heart in praise of God the Creator; being certain that he gives no less worship to God than the astronomer, to whom God has given to see more clearly with his inward eye, and who, for what he has himself discovered, both can and will glorify God."

The next great step in our knowledge of the universe, the discovery of the mechanical causes by which its motions are produced, and of their laws, has in modern times sometimes been supposed, both by the friends of religion and by others, to be unfavourable to the impression of an intelligent first cause. That such a supposition is founded in error we have offered what appear to us insurmountable reasons for believing. That in the mind of the great discoverer of this mechanical cause, Newton, the impression of a creating and presiding Deity was confirmed, not shaken, by all his discoveries, is so well known that it is almost superfluous to insist upon the fact. His views of the tendency of science invested it with no dangers of this kind. "The business of natural philosophy is," he says, (Optics, Qu. 28.) "to argue from phenomena without eigning hypotheses, and to deduce causes from effects, till we come to the very first cause, which certainly is not mechanical." "Though every true step made in this philosophy brings us not immediately to the knowledge of the first cause, yet it brings us nearer to it and is on that account highly to be valued." The Scholium, or note, which concludes this great work, the Principia, is a well known and most striking evidence on this point, "This beautiful system of sun, planets, and comets, could have its origin in no other way than by the purpose and command of an intelligent and powerful Being. He governs all things, not as the soul of the world, but as the lord of the universe. He is not only God, but Lord or Governor. We know him only by his properties and attributes, by the wise and admirable structure of things around us, and by their

final causes; we admire him on account of his perfections, we venerate and worship him on account of his government."

Without making any further quotations, it must be evident to the reader that the succession of great philosophers through whom mankind have been led to the knowledge of the greatest of scientific truths, the law of universal gravitation, did, for their parts, see the truths which they disclosed to men in such a light that their religious feelings, their reference of the world to an intelligent Creator and Preserver, their admiration of his attributes, were exalted rather than impaired by the insight which they obtained into the structure of the universe.

Having shown this with regard to the most perfect portion of human knowledge, our knowledge of the motions of the solar system, we shall adduce a few other passages, illustrating the prevalence of the same fact in other departments of experimental science; although, for reasons which have already been intimated, we conceive that sciences of experiment do not conduct so obviously as sciences of observation do the impression of a Divine Legislator of the material world.

The science of Hydrostatics was constructed in a great measure by the founders of the sister science of Mechanics. Of those who were employed in experimentally establishing the principles peculiarly belonging to the doctrine of fluids, Pascal and Boyle are two of the most eminent names. That these two great philosophers were not only religious, but both of them remarkable for their fervent and pervading devotion, is too well known to be dwelt on. With regard to Pascal, however, we ought not perhaps to pass over an opinion of his, that the existence of God cannot be proved from the external world. "I do not undertake to prove this," says he, "not only because I do not feel myself sufficiently strong to find in nature that which shall convince obstinate atheists, but because such knowledge without Jesus Christ is useless and sterile." It is obvious that such a state of mind would prevent this writer from encouraging or dwelling upon the grounds of natural religion; while yet he himself is an example of that which we wish to illustrate, that those who have obtained the furthest insight into nature, have been in all ages firm believers in God. "Nature," he says in another place, "has perfections in order to show that she is the image of God, and defects in order to show that she is only his image."*

Boyle was not only a most pious man as well as a great philosopher, but he exerted himself very often and earnestly in his writings to show the bearing of his natural philosophy upon his views of the Divine attributes, and of the government of the world. Many of these dissertations convey trains of thought and reason-

* Pensées, Art. viii. 1.

ing which have never been surpassed for their combination of judicious sobriety in not pressing his arguments too far, with fervent devotion in his conceptions of the Divine nature. As examples of these merits, we might adduce almost any portion of his tracts on these subjects; for instance, his "Inquiry into the Final Causes of Natural Things;" his "Free Inquiry into the Vulgar Notion of Nature;" his "Christian Virtuoso;" and his Essay entitled "The High Veneration Man's Intellect owes to God." It would be superfluous to quote at any length from these works. We may observe, however, that he notices that general fact which we are at present employed in exemplifying, that "in almost all ages and countries the generality of philosophers and contemplative men were persuaded of the existence of a Deity from the consideration of the phenomena of the universe; whose fabric and conduct they rationally concluded could not justly be ascribed either to chance or to any other cause than a Divine Being." And in speaking of the religious uses of science, he says: "Though I am willing to grant that some impressions of God's wisdom are so conspicuous that even a superficial philosopher may thence infer that the author of such works must be a wise agent; yet how wise an agent he has in these works expressed himself to be, none but an experimental philosopher can well discern. And 'tis not by a slight survey, but by a diligent and skilful scrutiny, of the works of God, that a man must be, by a rational and affective conviction, engaged to acknowledge that the author of nature 'is wonderful in counsel, and excellent in working.'"

After the mechanical properties of fluids, the laws of the operation of the chemical and physical properties of the elements about us, offer themselves to our notice. The relations of heat and of moisture in particular, which play so important a part, as we have seen, in the economy of our world, have been the subject of various researches: and they have led to views of the operation of such agents, some of which we have endeavoured to present to the reader, and to point out the remarkable arrangements by which their beneficial operation is carried on. That the discoverers of the laws by which such operations are regulated, were not insensible to the persuasion of a Divine care and contrivance which those arrangements suggest, is what we should expect, in agreement with what we have already said, and it is what we find. Among the names of the philosophers to whom we owe our knowledge on these subjects, there are none greater than those of Black, the discoverer of the laws of latent heat, and Dalton, who first gave us a true view of the mode in which watery vapour exists and operates in the atmosphere. With regard to the former of these philosophers, we shall quote Dr. Thomson's account of the views

which the laws of latent heat suggested to the discoverer.* "Dr. Black quickly perceived the vast importance of this discovery, and took a pleasure in laying before his students a view of the beneficial effects of this habitude of heat in the economy of nature. During the summer season a vast magazine of heat is accumulated in the water, which by gradually emerging during congelation serves to temper the cold of winter. Were it not for this accumulation of heat in water and other bodies, the sun would no sooner go a few degrees to the south of the equator than we should feel all the horrors of winter."

In the same spirit are Mr. Dalton's reflexions, after pointing out the laws which regulate the balance of evaporation and rain,† which he himself first clearly explained. "It is scarcely possible," says he, "to contemplate without admiration the beautiful system of nature by which the surface of the earth is continually supplied with water, and that unceasing circulation of a fluid so essentially necessary to the very being of the animal and vegetable kingdom takes place."

Such impressions appear thus to rise irresistibly in the breasts of men, when they obtain a sight, for the first time, of the varied play and comprehensive connexions of the laws by which the business of the material world is carried on and its occurrences brought to pass. To dwell upon or develope such reflexions is not here our business. Their general prevalence in the minds of those to whom these first views of new truths are granted, has been, we trust, sufficiently illustrated. Nor are the names adduced above, distinguished as they are, brought forwards as *authorities* merely. We do not claim for the greatest discoverers in the realms of science any immunity from error. In their general opinions they may, as others may, judge or reason ill. The articles of their religious belief may be as easily and as widely as of other men's, imperfect, perverted, unprofitable. But on this one point, the tendency of our advances in scientific knowledge of the universe to lead us up to a belief in a most wise maker and master of the universe, we conceive that they who make these advances, and who feel, as an original impression, that which others feel only by receiving their teaching, must be looked to with a peculiar attention and respect. And what their impressions have commonly been, we have thus endeavoured to show.

* Thomson's Hist. of Chemistry, vol. i. 321.
† Manch. Mem. vol. v. p. 346.

CHAPTER VI.

ON DEDUCTIVE HABITS; OR, ON THE IMPRESSION PRODUCED ON MEN'S MINDS BY TRACING THE CONSEQUENCES OF ASCERTAINED LAWS.

The opinion illustrated in the last chapter, that the advances which men make in science tend to impress upon them the reality of the Divine government of the world, has often been controverted. Complaints have been made, and especially of late years, that the growth of piety has not always been commensurate with the growth of knowledge, in the minds of those who make nature their study. Views of an irreligious character have been entertained, it is sometimes said, by persons eminently well instructed in all the discoveries of modern times, no less than by the superficial and ignorant. Those who have been supposed to deny or to doubt the existence, the providence, the attributes of God, have in many cases been men of considerable eminence and celebrity for their attainments in science. The opinion that this is the case, appears to be extensively diffused, and this persuasion has probably often produced inquietude and grief in the breasts of pious and benevolent men.

This opinion, concerning the want of religious convictions among those who have made natural philosophy their leading pursuit, has probably gone far beyond the limits of the real fact. But if we allow that there are any strong cases to countenance such an opinion, it may be worth our while to consider how far they admit of any satisfactory explanation. The fact appears at first sight to be at variance with the view we have given of the impression produced by scientific discovery; and it is moreover always a matter of uneasiness and regret, to have men of eminent talents and knowledge opposed to doctrines which we consider as important truths.

We conceive that an explanation of such cases, if they should occur, may be found in a very curious and important circumstance belonging to the process by which our physical sciences are formed. The first discovery of new general truths, and the developement of these truths when once obtained, are two operations extremely different; imply different mental habits, and may easily be associated with different views and convictions on points out of the reach of scientific demonstration. There would therefore be nothing surprising, or inconsistent with what we have maintained above, if it should appear that while original discoverers of laws of nature are peculiarly led, as we have seen, to believe the existence of a supreme intelligence and purpose; the far greater number of cultivators of science, whose employment it is to learn from others these general laws, and to trace, combine, and apply their consequences,

should have no clearness of conviction or security from error on this subject, beyond what belongs to persons of any other class.

This will, perhaps, become somewhat more evident by considering a little more closely the distinction of the two operations of discovery and developement, of which we have spoken above, and the tendency which the habitual prosecution of them may be expected to produce in the thoughts and views of the student.

We have already endeavoured in some measure to describe that which takes place when a new law of nature is discovered. A number of facts in which, before, order and connexion did not appear at all, or appeared by partial and contradictory glimpses, are brought into a point of view in which order and connexion become their essential character. It is seen that each fact is but a different manifestation of the same principle; that each particular is that which it is, in virtue of the same general truth. The inscription is decyphered; the enigma is guessed; the principle is understood; the truth is enunciated.

When this step is once made, it becomes possible to deduce from the truth thus established, a train of consequences often in no small degree long and complex. The process of making these inferences may properly be described by the word Deduction, while the very different process by which a new principle is collected from an assemblage of facts, has been termed Induction; the truths so obtained and their consequences constitute the results of the Inductive Philosophy; which is frequently and rightly described as a science which ascends from particular facts to general principles, and then descends again from these general principles to particular applications and exemplifications.

While the great and important labours by which science is really advanced consist in the successive steps of the *inductive* ascent, in the discovery of new laws perpetually more and more general; by far the greater part of our books of physical science unavoidably consists in *deductive* reasoning exhibiting the consequences and applications of the laws which have been discovered; and the greater part of writers upon science have their minds employed in this process of deduction and application.

This is true of many of those who are considered, and justly, as distinguished and profound philosophers. In the mechanical philosophy, that science which applies the properties of matter and the laws of motion to the explanation of the phenomena of the world, this is peculiarly the case. The laws, when once discovered, occupy little room in their statement, and when no longer contested, are not felt to need a lengthened proof. But their consequences require far more room and far more intellectual labour. If we take, for example, the laws of motion and the law of universal gravitation, we can express in a few lines, that which, when developed, represents and explains an innumerable mass of natural phenomena. But here

the course of developement is necessarily so long, the reasoning contains so many steps, the considerations on which it rests are so minute and refined, the complication of cases and of consequences is so vast, and even the involution arising from the properties of space and number so serious, that the most consummate subtlety, the most active invention, the most tenacious power of inference, the widest spirit of combination, must be tasked and tasked severely, in order to solve the problems which belong to this portion of science. And the persons who have been employed on these problems, and who have brought to them the high and admirable qualities which such an office requires, have justly excited in a very eminent degree the admiration which mankind feel for great intellectual powers. Their names occupy a distinguished place in literary history; and probably there are no scientific reputations of the last century higher, and none more merited, than those earned by the great mathematicians who have laboured with such wonderful success in unfolding the mechanism of the heavens; such for instance as D'Alembert, Clairault, Euler, Lagrange, Laplace.

But it is still important to recollect, that the mental employments of men, while they are occupied in this portion of the task of the formation of science, are altogether different from that which takes place in the mind of a discoverer, who, for the first time, seizes the principle which connects phenomena before unexplained, and thus adds another original truth to our knowledge of the universe. In explaining, as the great mathematicians just mentioned have done, the phenomena of the solar system by means of the law of universal gravitation, the conclusions at which they arrived were really included in the truth of the law itself, whatever skill and sagacity it might require to develope and extricate them from the general principle. But when Newton conceived and established the law itself, he added to our knowledge something which was not contained in any truth previously known, nor deducible from it by any course of mere reasoning. And the same distinction, in all other cases, obtains, between these processes which establish the principles, generally few and simple, on which our sciences rest, and those reasonings and calculations, founded on the principles thus obtained, which constitute by far the larger portion of the common treatises on the most complete of the sciences now cultivated.

Since the difference is so great between the process of inductive generalization of physical facts, and that of mathematical deduction of consequences, it is not surprising that the two processes should imply different mental powers and habits. However rare the mathematical talent, in its highest excellence, may be, it is far more common, if we are to judge from the history of science, than the genius which divines the general laws of nature. We have

several good mathematicians in every age; we have few great discoverers in the whole history of our species.

The distinction being thus clearly established between original discovery and derivative speculation, between the ascent to principles and the descent from them, we have further to observe, that the habitual and exclusive prosecution of the latter process may sometimes exercise an unfavourable effect on the mind of the student, and may make him less fitted and ready to apprehend and accept truths different from those with which his reasonings are concerned. We conceive, for example, that a person labours under gross error, who believes the phenomena of the world to be altogether produced by mechanical causes, and who excludes from his view all reference to an Intelligent First Cause and Governor. But we conceive that reasons may be shown which make it more probable that error of such a kind should find a place in the mind of a person of deductive, than of inductive habits;—of a mere mathematician or logician, than of one who studies the facts of the natural world and detects their laws.

The person whose mind is employed in reducing to law and order and intelligible cause the complex facts of the material world, is compelled to look beyond the present state of his knowledge, and to turn his thoughts to the existence of principles higher than those which he yet possesses. He has seen occasions when facts that at first seemed incoherent and anomalous, were reduced to rule and connexion; and when limited rules were discovered to be included in some rule of superior generality. He knows that all facts and appearances, all partial laws, however confused and casual they at present seem, must still, in reality, have this same kind of bearing and dependence;—must be bound together by some undiscovered principle of order;—must proceed from some cause working by most steady rules;—must be included in some wide and fruitful general truth. He cannot therefore consider any principles which he has already obtained, as the ultimate and sufficient reason of that which he sees. There must be some higher principle, some ulterior reason. The effort and struggle by which he endeavours to extend his view, makes him feel that there is a region of truth not included in his present physical knowledge; the very imperfection of the light in which he works his way, suggests to him that there must be a source of clearer illumination at a distance from him.

We must allow that it is scarcely possible to describe in a manner free from some vagueness and obscurity, the effect thus produced upon the mind by the efforts which it makes to reduce natural phenomena to general laws. But we trust it will still be allowed that there is no difficulty in seeing clearly that a different iufluence may result from this process, and from the process of deductive reasoning which forms the main employment of the mathematical

cultivators and systematic expositors of physical science in modern times. Such persons are not led by their pursuits to anything beyond the general principles, which form the basis of their explanations and applications. They acquiesce in these; they make these their ultimate grounds of truth; and they are entirely employed in unfolding the particular truths which are involved in the general truth. Their thoughts dwell little upon the possibility of the laws of nature being other than we find them to be, or on the reasons why they are not so; and still less on those facts and phenomena which philosophers have not yet reduced to any rule; which are lawless to us, though we know that, in reality, they are governed by some principle of order and harmony. On the contrary, by assuming perpetually the existing laws as the basis of their reasoning, without question or doubt, and by employing such language that these laws can be expressed in the simplest and briefest form, they are led to think and believe as if these laws were necessarily and inevitably what they are. Some mathematicians indeed have maintained that the highest laws of nature with which we are acquainted, the laws of motion and the law of universal gravitation, are not only necessarily true, but are even self-evident and certain *a priori*, like the truths of geometry. And though the mathematical cultivator of the science of mechanics may not adopt this as his speculative opinion, he may still be so far influenced by the tendency from which it springs, as to rest in the mechanical laws of the universe as ultimate and all-sufficient principles, without seeing in them any evidence of their having been selected and ordained, and thus without ascending from the world to the thought of an Intelligent Ruler. He may thus substitute for the Deity certain axioms and first principles, as the cause of all. And the follower of Newton may run into the error with which he is sometimes charged, of thrusting some mechanic cause into the place of God, if he do not raise his views, as his master did, to some higher cause, to some source of all forces, laws, and principles.

When, therefore, we consider the mathematicians who are employed in successfully applying the mechanical philosophy, as men well deserving of honour from those who take an interest in the progress of science, we do rightly; but it is still to be recollected, that in doing this they are not carrying us to any higher point of view in the knowledge of nature than we had attained before: they are only unfolding the consequences, which were already virtually in our possession, because they were implied in principles already discovered:—they are adding to our knowledge of effects, but not to our knowledge of causes:—they are not making any advance in that progress of which Newton spoke, and in which he made so vast a stride, in which "every step made brings us nearer to the knowledge of the first cause, and is on that account highly to be valued." And as in this advance they have no peculiar privileges or ad-

vantages, their errors of opinion concerning it, if they err, are no more to be wondered at, than those of common men; and need as little disturb or distress us, as if those who committed them had confined themselves to the study of arithmetic or of geometry. If we can console and tranquillize ourselves concerning the defective or perverted views of religious truth entertained by any of our fellow men, we need find no additional difficulty in doing so when those who are mistaken are great mathematicians, who have added to the riches and elegance of the mechanical philosophy. And if we are seeking for extraneous grounds of trust and comfort on this subject, we may find them in the reflection;—that, whatever may be the opinions of those who assume the causes and laws of that philosophy and reason from them, the views of those admirable and ever-honoured men who first caught sight of these laws and causes, impressed *them* with the belief that this is "the fabric of a great and good God;" that "it is man's duty to pour out his soul in praise of the Creator;" and that all this beautiful system must be referred to "a first cause, which is certainly not mechanical."

2. We may thus, with the greatest propriety, deny to the mechanical philosophers and mathematicians of recent times any authority with regard to their views of the administration of the universe; we have no reason whatever to expect from their speculations any help, when we attempt to ascend to the first cause and supreme ruler of the universe. But we might perhaps go further, and assert that they are in some respects less likely than men employed in other pursuits, to make any clear advance towards such a subject of speculation. Persons whose thoughts are thus entirely occupied in deduction are apt to forget that this is, after all, only one employment of the reason among more; only one mode of arriving at truth, needing to have its deficiencies completed by another. Deductive reasoners, those who cultivate science, of whatever kind, by means of mathematical and logical processes alone, may acquire an exaggerated feeling of the amount and value of their labours. Such employments, from the clearness of the notions involved in them, the irresistible concatenation of truths which they unfold, the subtlety which they require, and their entire success in that which they attempt, possess a peculiar fascination for the intellect. Those who pursue such studies have generally a contempt and impatience of the pretensions of all those other portions of our knowledge, where from the nature of the case, or the small progress hitherto made in their cultivation, a more vague and loose kind of reasoning seems to be adopted. Now if this feeling be carried so far as to make the reasoner suppose that these mathematical and logical processes can lead him to all the knowledge and all the certainty which we need, it is clearly a delusive feeling. For it is confessed on all hands, that all which mathematics or which logic can do, is to develope and extract those truths, as conclusions, which were in

reality involved in the principles on which our reasonings proceeded.* And this being allowed, we cannot but ask how we obtain these principles? from what other source of knowledge we derive the original truths which we thus pursue into detail? since it is manifest that such principles cannot be derived from the proper stores of mathematics or logic. These methods can generate no new truth; and all the grounds and elements of the knowledge which, through them, we can acquire, must necessarily come from some extraneous source. It is certain, therefore, that the mathematician and the logician must derive from some process different from their own, the substance and material of all our knowledge, whether physical or metaphysical, physiological or moral. This process, by which we acquire our first principles, (without pretending here to analyse it,) is obviously the general course of human experience, and the natural exercise of the understanding; our intercourse with matter and with men, and the consequent growth in our minds of convictions and conceptions such as our reason can deal with, either by her systematic or unsystematic methods of procedure. Supplies from this vast and inexhaustible source of original truths are requisite, to give any value whatever to the results of our deductive processes, whether mathematical or logical; while, on the other hand, there are many branches of our knowledge, in which we possess a large share of original and derivative convictions and truths, but where it is nevertheless at present quite impossible to erect our knowledge into a complete system;—to state our primary and independent truths, and to show how on these all the rest depend by the rules of art. If the mathematician is repelled from speculations on morals or politics, on the beautiful or the right, because the reasonings which they involve have not mathematical precision and conclusiveness, he will remain destitute of much of the most valuable knowledge which man can acquire. And if he attempts to mend the matter by giving to treatises on morals, or politics, or criticism, a form and a phraseology borrowed from the very few tolerably complete physical sciences which exist, it will be found that he is compelled to distort and damage the most important truths, so as to deprive them of their true shape and import, in order to force them into their places in his artificial system.

If therefore, as we have said, the mathematical philosopher dwells in his own bright and pleasant land of deductive reasoning, till he turns with disgust from all the speculations, necessarily less clear and conclusive, in which his imagination, his practical faculties, his

* "Since all reasoning may be resolved into syllogisms, and since in a syllogism the premises do virtually assert the conclusion, it follows at once, that no new truth can be elicited by any process of reasoning."—*Whately's Logic*, p. 223.

Mathematics is the *logic of quantity*, and to this science the observation here quoted is strictly applicable.

moral sense, his capacity of religious hope and belief, are to be called into action, he becomes, more than common men, liable to miss the road to truths of extreme consequence.

This is so obvious, that charges are frequently brought against the study of mathematics, as unfitting men for those occupations which depend upon our common instinctive convictions and feelings, upon the unsystematic exercise of the understanding with regard to common relations and common occurrences. Bonaparte observed of Laplace, when he was placed in a public office of considerable importance, that he did not discharge it in so judicious and clear-sighted a manner as his high intellectual fame might lead most persons to expect.* "He sought," that great judge of character said, "subtleties in every subject, and carried into his official employments the spirit of the method of infinitely small quantities," by which the mathematician solves his more abstruse problems. And the complaint that mathematical studies make men insensible to moral evidence and to poetical beauties, is so often repeated as to show that some opposition of tendency is commonly perceived between that exercise of the intellect which mathematics requires and those processes which go on in our minds when moral character or imaginative beauty is the subject of our contemplation.

Thus, while we acknowledge all the beauty and all the value of the mathematical reasonings by which the consequences of our general laws are deduced, we may yet consider it possible that a philosopher, whose mind has been mainly employed, and his intellectual habits determined, by this process of deduction, may possess, in a feeble and imperfect degree only, some of those faculties by which truth is attained, and especially those truths which regard our relation to that mind, the origin of all law, the source of first principles, which must be immeasurably elevated above all derivative truths. It would, therefore, be far from surprising, if there should be found, among the great authors of the developements of the mechanical philosophy, some who had refused to refer the phenomena of the universe to a supreme mind, purpose, and will. And though this world be, to a believer in the Being and government of God, a matter of sorrow and pain, it need not excite more surprise than if the same were true of a person of most ordinary endowments, when it is recollected in what a disproportionate manner the various faculties of such a philosopher may have been cultivated. And our apprehensions of injury to mankind from the influence of such examples will diminish, when we consider, that those mathe-

* A l'intérieur le ministre Quinette fut remplacé par Laplace, géomêtre du premier rang, mais qui ne tarda pas à se montrer administrateur plus que médiocre : dès son premier travail les consuls s'aperçurent qu'ils s'étaient trompés : Laplace ne saisissait aucune question sous son vrai point de vue ; il cherchait des subtilités partout, n'avait que des idées problématiques, et portait enfin l'esprit des infiniment petits dans l'administration.—*Mémoires écrits à Ste. Hélène*, i. 3.

maticians whose minds have been less partially exercised, the great discoverers of the truths which others apply, the philosophers who have looked upwards as well as downwards, to the unknown as well as to the known, to ulterior as well as proximate principles, have never rested in this narrow and barren doctrine; but have perpetually looked forwards, beyond mere material laws and causes, to a First Cause of the moral and material world, to which each advance in philosophy might bring them nearer, though it must ever remain indefinitely beyond their reach.

It scarcely needs, perhaps, to be noticed, that what we here represent as the possible source of error is, not the perfection of the mathematical habits of the mind, but the deficiency of the habit of apprehending truth of other kinds;—not a clear insight into the mathematical consequences of principles, but a want of a clear view of the nature and foundation of principles;—not the talent for generalizing geometrical or mechanical relations, but the tendency to erect such relations into ultimate truths and efficient causes. The most consummate mathematical skill may accompany and be auxiliary to the most earnest piety, as it often has been. And an entire command of the conceptions and processes of mathematics is not only consistent with, but is the necessary condition and principal instrument of every important step in the discovery of physical principles. Newton was eminent above the philosophers of his time, in no one talent so much as in the power of mathematical deduction. When he had caught sight of the law of universal gravitation, he traced it to its consequences with a rapidity, a dexterity, a beauty of mathematical reasoning which no other person could approach; so that on this account, if there had been no other, the establishment of the general law was possible to him alone. He still stands at the head of mathematicians as well as of philosophical discoverers. But it never appeared to him, as it may have appeared to some mathematicians who have employed themselves on his discoveries, that the general law was an ultimate and sufficient principle: that the point to which he had hung his chain of deduction was the highest point in the universe. Lagrange, a modern mathematician of transcendent genius, was in the habit of saying, in his aspirations after future fame, that Newton was fortunate in having had the system of the world for his problem, since its theory could be discovered once only. But Newton himself appears to have had no such persuasion that the problem he had solved was unique and final; he laboured to reduce gravity to some higher law, and the forces of other physical operations to an analogy with those of gravity, and declared that all these were but steps in our advance towards a first cause. Between us and this first cause, the source of the universe and of its laws, we cannot doubt that there intervene many successive steps of possible discovery and generalization, not less wide and striking than the discovery of universal gra-

vitation: but it is still more certain that no extent or success of physical investigation can carry us to any point which is not at an immeasurable distance from an adequate knowledge of Him.

CHAPTER VII.

ON FINAL CAUSES.

We have pointed out a great number of instances where the mode in which the arrangements of nature produce their effect, suggests, as we conceive, the belief that this effect is to be considered as the *end* and *purpose* of these arrangements. The impression which thus arises, of design and intention exercised in the formation of the world, or of the reality of *Final Causes*, operates on men's minds so generally, and increases so constantly on every additional examination of the phenomena of the universe, that we cannot but suppose such a belief to have a deep and stable foundation. And we conceive that in several of the comparatively few cases in which such a belief has been rejected, the averseness to it has arisen from the influence of some of the causes mentioned in the last chapter; the exclusive pursuit, namely, of particular trains and modes of reasoning, till the mind becomes less capable of forming the conceptions and making the exertions which are requisite for the apprehension of truths not included among its usual subjects of thought.

1. This seems to be the case with those who maintain that purpose and design cannot be *inferred* or *deduced* from the arrangements which we see around us by any process of reasoning. We can reason from effects to causes, say such writers, only in cases where we know something of the nature of the cause. We can infer from the works of men, the existence of design and purpose, because we know, from past observation, what kind of works human design and purpose can produce. But the universe, considered as the work of God, cannot be compared with any corresponding work, or judged of by any analogy with know examples. How then can we, in this case, they ask, infer design and purpose in the artist of the universe? On what principles, on what axioms, can we proceed, which shall include this necessarily singular instance, and thus give legitimacy and validity to our reasonings?

What has already been said on the subject of the two different processes by which we obtain principles, and by which we reason from them, will suggest the reply to these questions. When we collect design and purpose from the arrangements of the universe, we do not arrive at our conclusion by a train of deductive reason-

ing, but by the conviction which such combinations as we perceive immediately and directly impress upon the mind. "Design must have had a designer." But such a principle can be of no avail to one whom the contemplation or the description of the world does not impress with the perception of design. It is not therefore at the end, but at the beginning of our syllogisms, not among remote conclusions, but among original principles, that we must place the truth, that such arrangements, manifestations, and proceedings as we behold about us imply a Being endowed with consciousness, design, and will, from whom they proceed.

This is inevitably the mode in which such a conviction is acquired; and that it is so, we may the more readily believe, when we consider that it is the case with the design and will which we ascribe to man, no less than in that which we believe to exist in God. At first sight we might perhaps be tempted to say, that we infer design and purpose from the works of man in one case, because we have known these attributes in other cases produce effects in some measure similar. But to this we must reply, by asking how we come to know the existence of human design and purpose *at first*, and *at all?* What we see around us are certain appearances, things, successions of events; how come we ever to ascribe to other men the thought and will of which we are conscious ourselves? How do we come to believe that there are other men? How are we led to elevate, in our conceptions, some of the *objects* which we perceive into *persons?* No doubt their actions, their words induce us to do this. We see that the manifestations which we observe must be so understood, and no otherwise. We feel that such actions, such events must be connected by consciousness and personality; that the actions are not the actions of things, but of persons; not necessary and without significance, like the falling of a stone, but voluntary and with purpose like what we do ourselves. But this is not the result of reasoning: we do not infer this from any similar case which we have known; since we are now speaking of the *first* conception of a will and purpose different from our own. In arriving at such knowledge, we are aided only by our own consciousness of what thought, purpose, will, are: and possessing this regulative principle, we so decypher and interpret the complex appearances which surround us, that we receive irresistibly the persuasion of the existence of other men, with thought and will and purpose like our own. And just in the same manner, when we examine attentively the adjustment of the parts of the human frame to each other and to the elements, the relation of the properties of the earth to those of its inhabitants, or of the physical to the moral nature of man, the thought must arise and cling to our perceptions, however little it be encouraged, that this system, every where so full of wonderful combinations, suited to the preservation, and well-being of living crea-

tures, is also the expression of the intention, wisdom, and goodness of a personal creator and governor.

We conceive then that it is so far from being an unsatisfactory or unphilosophical process by which we collect the existence of a Deity from the works of creation, that the process corresponds most closely with that on which rests the most steadfast of our convictions, next to that of our own existence, the belief of the existence of other human beings. If any one ever went so far in scepticism as to doubt the existence of any other person than himself, he might, so far as the argument from final causes is concerned, reject the being of God as well as that of man; but without dwelling on the possibility of such fantasies, when we consider how impossible it is for men in general not to attribute personality, purpose, thought, will to each other, in virtue of certain combinations of appearances and actions, we must deem them most consistent and reasonable in attributing also personality and purpose to God, in virtue of the whole assemblage of appearances and actions which constitute the universe, full as it is of combinations from which such a suggestion springs. The vividness, the constancy of the belief of a wise and good Being, thus governing the world, may be different in different men, according to their habit of directing their thoughts on the subject; but such a belief is undoubtedly capable of becoming lively and steadfast in the highest degree. It has been entertained and cherished by enlightened and well-regulated minds in all ages; and has been, at least since the rise of Christianity, not only the belief, but a pervading and ruling principle of action of many men, and of whole communities. The idea may be rendered more faint by turning the mind away from it, and, perhaps by indulging too exclusively in abstract and general speculations. It grows stronger by an actual study of the details of the creation; and, as regards the practical consequences of such a belief, by a habit of referring our actions and hopes to such a Governor. In this way it is capable of becoming as real and fixed an impression as that of a human friend and master; and all that we can learn, by observing the course of men's feelings and actions, tends to convince us, that this belief of the being and presence and government of God, leads to the most elevated and beneficial frame of mind of which man is capable.

2. How natural and almost inevitable is this persuasion of the reality of Final Causes and consequent belief in the personality of the Deity, we may gather by observing how constantly it recurs to the thoughts, even of those who, in consequence of such peculiarities of mental discipline as have been described, have repelled and resisted the impression.

Thus, Laplace, of whom we have already spoken, as one of the greatest mathematicians of modern times, expresses his conviction that the supposed evidence of final causes will disappear as our

knowledge advances, and that they only seem to exist in those cases where our ignorance leaves room for such a mistake. "Let us run over," he says, "the history of the progress of the human mind and its errors: we shall perpetually see final causes pushed away to the bounds of its knowledge. These causes, which Newton removed to the limits of the solar system, were not long ago conceived to obtain in the atmosphere, and employed in explaining meteors: they are, therefore, in the eyes of the philosopher nothing more than the expression of the ignorance in which we are of the real causes."

We may observe that we have endeavoured to give a very different, and, as we believe, a far truer view of the effect which philosophy has produced on our knowledge of final causes. We have shown, we trust, that the notion of design and end is transferred by the researches of science, not from the domain of our knowledge to that of our ignorance, but merely from the region of facts to that of laws. We hold that, in this form, final causes in the atmosphere are still to be conceived to obtain, no less than in an earlier state of meteorological knowledge; and that Newton was right, when he believed that he had established their reality in the solar system, not expelled them from it.

But our more peculiar business at present is to observe that Laplace himself, in describing the arrangements by which the stability of the solar system is secured, uses language which shows how irresistibly these arrangements suggest an adaptation to its preservation as an *end*. If in his expressions we were to substitute the Deity for the abstraction "nature" which he employs, his reflexion would coincide with that which the most religious philosopher would entertain. "It seems that 'God' has ordered everything in the heavens to ensure the duration of the planetary system, by *views* similar to those which He appears to us so admirably to follow upon the earth, for the preservation of animals and the perpetuity of species.* This consideration alone would explain the disposition of the system, if it were not the business of the geometer to go further." It may be possible for the geometer to go further; but he must be strangely blinded by his peculiar pursuits, if, when he has discovered the mode in which these views are answered, he supposes himself to have obtained a proof that there are no views at all. It would be as if the savage, who had marvelled at the steady working of the steam engine, should cease to consider it a work of art, as soon as the self-regulating part of the mechanism had been explained to him.

The unsuccessful struggle in which those persons engage, who attempt to throw off the impression of design in the creation, appears

* Il semble que la nature ait tout disposé dans le ciel, pour assurer la durée du système planétaire, par des vues semblables à celles qu'elle nous paraît suivre si admirablement sur la terre, pour la conservation des individus et la perpétuité des espèces.—*Syst. du Monde*, p. 442.

in an amusing manner through the simplicity of the ancient Roman poet of this school. Lucretius maintains that the eye was not made for seeing, nor the ear for hearing. But the terms in which he recommends this doctrine show how hard he knew it to be for men to entertain such an opinion. His advice is,—

> Illud, in his rebus vitium *vehementer* et istum
> Effugere errorem, vitareque *præmeditator*,
> Lumina ne facias oculorum clara creata,
> Prospicere ut possimus. iv. 823.
>
> 'Gainst their preposterous error guard thy mind
> Who say each organ was for use design'd;
> Think not the visual orbs, so clear, so bright,
> Were furnish'd for the purposes of sight.

Undoubtedly the poet is so far right, that a most "vehement" caution and vigilant "premeditation" are necessary to avoid the "vice and error" of such a persuasion. The study of the adaptations of the human frame is so convincing, that it carries the mind with it, in spite of the resistance suggested by speculative systems. Cabanis, a modern French physiological writer of great eminence, may be selected as a proof of this. Both by the general character of his own speculations, and by the tone of thinking prevalent around him, the consideration of design in the works of nature was abhorrent from his plan. Accordingly, he joins in repeating Bacon's unfavourable mention of final causes. Yet when he comes to speak of the laws of reproduction of the human race, he appears to feel himself compelled to admit the irresistible manner in which such views force themselves on the mind. "I regard," he says, "with the great Bacon, the philosophy of final causes as barren; but I have elsewhere acknowledged that it was very difficult for the most cautious man (l'homme le plus reservé) never to have recourse to them in his explanations."*

3. It may be worth our while to consider for a moment the opinion here referred to by Cabanis, of the propriety of excluding the consideration of final causes from our natural philosophy. The great authority of Bacon is usually adduced on this subject. "The handling of final causes," says he, "mixed with the rest in physical inquiries, hath intercepted the severe and diligent inquiry of all real and physical causes, and given men the occasion to stay upon these satisfactory and specious causes, to the great arrest and prejudice of farther discovery."†

A moment's attention will show how well this representation agrees with that which we have urged, and how far it is from dissuading the reference to final causes in reasonings like those on which we are employed. Final causes are to be excluded *from physical inquiry;* that is, we are not to assume that we know the

* Rapports du Physique et du Moral de l'Homme. i. 299.
† De Augment. Sc. ii. 105.

objects of the Creator's design, and put this assumed purpose in the place of a physical cause. We are not to think it a sufficient account of the clouds that they are for watering the earth, (to take Bacon's examples,) or "that the solidness of the earth is for the station and mansion of living creatures." The physical philosopher has it for his business to trace clouds to the laws of evaporation and condensation; to determine the magnitude and mode of action of the forces of cohesion and crystallization by which the materials of the earth are made solid and firm. This he does, making no use of the notion of final causes: and it is precisely because he has thus established his theories independently of any assumption of an end, that the end, when, after all, it returns upon him and cannot be evaded, becomes an irresistible evidence of an intelligent legislator. He finds that the effects, of which the use is obvious, are produced by most simple and comprehensive laws; and when he has obtained this view, he is struck by the beauty of the means, by the refined and skilful manner in which the useful effects are brought about;—points different from those to which his researches were directed. We have already seen, in the very case of which we have been speaking, namely, the laws by which the clouds are formed and distribute their showers over the earth, how strongly those who have most closely and extensively examined the arrangements there employed (as Howard, Dalton, and Black) have been impressed with the harmony and beauty which these contrivances manifest.

We may find a further assertion of this view of the proper use of final causes in philosophy, by referring to the works of one of the greatest of our philosophers, and one of the most pious of our writers, Boyle, who has an Essay on this subject. "I am by all means," says he, "for encouraging the contemplation of the celestial part of the world, and the shining globes that adorn it, and especially the sun and moon, in order to raise our admiration of the stupendous power and wisdom of him who was able to frame such immense bodies; and notwithstanding their vast bulk and scarce conceivable rapidity, keep them for so many ages constant both to the lines and degrees of their motion, without interfering with one another. And doubtless we ought to return thanks and praises to the divine goodness for having so placed the sun and moon, and determined the former, or else the earth, to move in particular lines for the good of men and other animals; and how disadvantageous it would have been to the inhabitants of the earth if the luminaries had moved after a different manner. I dare not, however, affirm that the sun, moon, and other celestial bodies were made solely for the use of man: *much less presume to prove one system of the world to be true and another false; because the former is better fitted to the convenience of mankind, or the other less suited, or perhaps altogether useless to that end.*"

This passage exhibits, we conceive, that combination of feelings

which ought to mark the character of the religious natural philosopher; an earnest piety ready to draw nutriment from the contemplation of established physical truths; joined with a philosophical caution, is not seduced by the anticipation of such contemplations, to pervert the strict course of physical inquiry.

It is precisely through this philosophical care and scrupulousness that our views of final causes acquire their force and value as aids to religion. The object of such views is not to lead us to physical truth, but to connect such truth, obtained by its proper processes and methods, with our views of God, the master of the universe, through those laws and relations which are thus placed beyond dispute.

Bacon's comparison of final causes to the vestal virgins is one of those poignant sayings, so frequent in his writings, which it is not easy to forget. "Like them," he says, "they are dedicated to God, and are barren." But to any one who reads his work it will appear in what spirit this was meant. "Not because those final causes are not true and worthy to be inquired, being kept within their own province." (Of the Advancement of Learning, b. ii. p. 142.) If he had had occasion to develope his simile, full of latent meaning as his similes so often are, he would probably have said, that to these final causes barrenness was no reproach, seeing they ought to be, not the mothers but the daughters of our natural sciences; and that they were barren, not by imperfection of their nature, but in order that they might be kept pure and undefiled, and so fit ministers in the temple of God.

CHAPTER VIII.

ON THE PHYSICAL AGENCY OF THE DEITY.

1. We are not to expect that physical investigation can enable us to conceive the manner in which God acts upon the members of the universe. The question, "Canst thou by searching find out God?" must silence the boastings of science as well as the repinings of adversity. Indeed, science shows us, far more clearly than the conceptions of every day reason, at what an immeasurable distance we are from any faculty of conceiving *how* the universe, material and moral, is the work of the Deity. But with regard to the material world, we can at least go so far as this;—we can perceive that events are brought about, not by insulated interpositions of divine power exerted in each particular case, but by the establishment of general laws. This, which is the view of the universe

proper to science, whose office it is to search out these laws, is also the view of which, throughout this work, we have endeavoured to keep present to the mind of the reader. We have attempted to show that it combines itself most readily and harmoniously with the doctrines of Natural Theology; that the arguments for those doctrines are strengthened, the difficulties which affect them removed, by keeping it steadily before us. We conceive, therefore, that the religious philosopher will do well to bear this conception in his mind. God is the author and governor of the universe through the laws which he has given to its parts, the properties which he has impressed upon its constituent elements: these laws and properties are, as we have already said, the instruments with which he works: the institution of such laws, the selection of the quantities which they involve, their combination and application, are the modes in which he exerts and manifests his power, his wisdom, his goodness: through these attributes, thus exercised, the Creator of all, shapes, moves, sustains, and guides the visible creation.

This has been the view of the relation of the Deity to the universe entertained by the most sagacious and comprehensive minds ever since the true object of natural philosophy has been clearly and steadily apprehended. The great writer who was the first to give philosophers a distinct and commanding view of this object, thus expresses himself in his "Confession of Faith:" "I believe—that notwithstanding God hath rested and ceased from creating since the first Sabbath, yet, nevertheless, he doth accomplish and fulfil his divine will in all things, great and small, singular and general, as fully and exactly by providence, as he could by miracle and new creation, though his working be not immediate and direct, but by compass; not violating Nature, which is his own law upon the creature."

And one of our own time, whom we can no longer hesitate to place among the worthiest disciples of the school of Bacon, conveys the same thought in the following passages: "The Divine Author of the universe cannot be supposed to have laid down particular laws, enumerating all individual contingencies, which his materials have understood and obey—this would be to attribute to him the imperfections of human legislation;—but rather, by creating them endowed with certain fixed qualities and powers, he has impressed them in their origin with the *spirit*, not the letter of his law, and made all their subsequent combinations and relations inevitable consequences of this first impression."*

2. This, which thus appears to be the mode of the Deity's operation in the material world, requires some attention on our part in order to understand it with proper clearness. One reason of this is, that it is the mode of operation altogether different from that in

* Herschel on the Study of Nat. Phil. Art. 27.

which we are able to make matter fulfil our designs. Man can construct exquisite machines, can call in vast powers, can form extensive combinations, in order to bring about the results which he has in view. But in all this he is only taking advantage of laws of nature which already exist; he is applying to his use qualities which matter already possesses. Nor can he by any effort do more. He can establish no new law of nature which is not a result of the existing ones. He can invest matter with no new properties which are not modifications of its present attributes. His greatest advances in skill and power are made when he calls to his aid forces which before existed unemployed, or when he discovers so much of the habits of some of the elements as to be able to bend them to his purpose. He navigates the ocean by the assistance of the winds which he cannot raise or still: and even if we suppose him able to control the course of these, his yet unsubjugated ministers, this could only be done by studying their characters, by learning more thoroughly the laws of air and heat and moisture. He cannot give the minutest portion of the atmosphere new relations, a new course of expansion, new laws of motion. But the Divine operations, on the other hand, include something much higher. They take in the establishment of the laws of the elements, as well as the combination of these laws and the determination of the distribution and quantity of the materials on which they shall produce their effect. We must conceive that the Supreme Power has ordained that air shall be rarefied, and water turned into vapour, by heat; no less than that he has combined air and water so as to sprinkle the earth with showers, and determined the quantity of heat and air and water, so that the showers shall be as beneficial as they are.

We may and must, therefore, in our conceptions of the Divine purpose and agency, go beyond the analogy of human contrivances. We must conceive the Deity, not only as constructing the most refined and vast machinery, with which, as we have already seen, the universe is filled; but we must also imagine him as establishing those properties by which such machinery is possible: as giving to the materials of his structure the qualities by which the material is fitted to its use. There is much to be found, in natural objects, of the same kind of contrivance which is common to these and to human inventions; there are mechanical devices, operations of the atmospheric elements, chemical processes;—many such have been pointed out, many more exist. But besides these cases of the combination of means, which we seem able to understand without much difficulty, we are led to consider the Divine Being as the *author of the laws* of chemical, of physical, and of mechanical action, and of such other laws as make matter what it is;—and this is a view which no analogy of human inventions, no knowledge of human powers, at all assists us to embody or understand. Science, therefore, as we have said, while it discloses to us the mode of instru-

mentality employed by the Deity, convinces us, more effectually than ever, of the impossibility of conceiving God's actions by assimilating them to our own.

3. The laws of material nature, such as we have described them, operate at all times, and in all places; affect every province of the universe, and involve every relation of its parts. Wherever these laws appear, we have a manifestation of the intelligence by which they were established. But a law supposes an agent, and a power; for it is the mode according to which the agent proceeds, the order according to which the power acts. Without the presence of such an agent, of such a power, conscious of the relations on which the law depends, producing the effects which the law prescribes, the law can have no efficacy, no existence. Hence we infer that the intelligence by which the law is ordained, the power by which it is put in action, must be present at all times and in all places where the effects of the law occur; that thus the knowledge and the agency of the Divine Being pervade every portion of the universe, producing all action and passion, all permanence and change. The laws of nature are the laws which he, in his wisdom, prescribes to his own acts; his universal presence is the necessary condition of any course of events, his universal agency the only origin of any efficient force.

This view of the relation of the universe to God has been entertained by many of the most eminent of those who have combined the consideration of the material world with the contemplation of God himself. It may therefore be of use to illustrate it by a few quotations, and the more so, as we find this idea remarkably dwelt upon in the works of that writer whose religious views must always have a peculiar interest for the cultivators of physical science, the great Newton.

Thus, in the observations on the nature of the Deity with which he closes the "Optics," he declares the various portions of the world, organic and inorganic, "can be the effect of nothing else than the wisdom and skill of a powerful everliving Agent, who being in all places, is more able by his will to move the bodies within his boundless uniform *sensorium*, and thereby to form and reform the parts of the universe, than we are by our will to move the parts of our own bodies." And in the Scholium at the end of the "Principia," he says, "God is one and the same God always and everywhere. He is omnipresent, not by means of his *virtue* alone, but also by his *substance*, for virtue cannot subsist without substance. In him all things are contained, and move, but without mutual passion: God is not acted upon by the motions of bodies; and they suffer no resistance from the omnipresence of God." And he refers to several passages confirmatory of this view, not only in the Scriptures, but also in writers who hand down to us the opinions of some of the most philosophical thinkers of the pagan world. He does not disdain to quote the poets, and among the rest, the verses of Virgil;

> Principio cœlum ac terras camposque liquentes
> Lucentemque globum lunæ, Titaniaque astra,
> Spiritus intus alit, totamque infusa per artus
> Mens agitat molem et magno se corpore miscet;

warning his reader however against the doctrine which such expressions as these are sometimes understood to express. "All these things he rules, not as *the soul of the world*, but as the Lord of all."

Clarke, the friend and disciple of Newton, is one of those who has most strenuously put forwards the opinion of which we are speaking, "All things which we commonly say are the effects of the natural powers of matter and laws of motion, are indeed (if we will speak strictly and properly,) the effects of God's acting upon matter continually and at every moment, either immediately by himself, or mediately by some created intelligent being. Consequently there is no such thing as the course of nature, or the power of nature," independent of the effects produced by the will of God.

Dugald Stewart has adopted and illustrated the same opinion, and quotes with admiration the well-known passage of Pope, concerning the Divine Agency, which

> "Lives through all life, extends through all extent,
> Spreads undivided, operates unspent."

Mr. Stewart, with no less reasonableness than charity, asserts the propriety of interpreting such passages according to the scope and spirit of the reasonings with which they are connected;* since, though by a captious reader they might be associated with erroneous views of the Deity, a more favourable construction will often see in them only the results of the necessary imperfection of our language, when we dwell upon the omnipresence and universal activity of God.

Finally, we may add that the same opinions still obtain the assent of the best philosophers and divines of our time. Sir John Herschel says, (Discourse on the Study of Natural Philosophy, p. 37.) "We would no way be understood to deny the constant exercise of His direct power in maintaining the system of nature; or the ultimate emanation, of every energy which material agents exert, from his immediate will, acting in conformity with his own laws." And the Bishop of London, in a note to his "Sermon on the duty of combining religious instruction with intellectual culture," observes, "the student in natural philosophy will find rest from all those perplexities which are occasioned by the obscurity of causation, in the supposition, which although it was discredited by the patronage of Malebranche and the Cartesians, has been adopted by Clarke and Dugald Stewart, and which is by far the most simple and sublime

* Elem. of Phil. ii. p. 273.

account of the matter; that all the events, which are continually taking place in the different parts of the material universe, are the *immediate* effects of the Divine Agency."

CHAPTER IX.

ON THE IMPRESSION PRODUCED BY CONSIDERING THE NATURE AND PROSPECTS OF SCIENCE; OR, ON THE IMPOSSIBILITY OF THE PROGRESS OF OUR KNOWLEDGE EVER ENABLING US TO COMPREHEND THE NATURE OF THE DEITY.

If we were to stop at the view presented in the last chapter, it might be supposed that—by considering God as eternal and omnipresent, conscious of all the relations, and of all the objects of the universe, instituting laws founded on the contemplation of these relations, and carrying these laws into effect by his immediate energy,—we had tatained to a conception, in some degree definite, of the Deity, such as natural philosophy leads us to conceive him. But by resting in this mode of conception, we should overlook, or at least should disconnect from our philosophical doctrines, all that most interests and affects us in the character of the Creator and Preserver of the world;—namely, that he is the lawgiver and judge of our actions: the proper object of our prayer and adoration; the source from which we may hope for moral strength here, and for the reward of our obedience and the elevation of our nature in another state of existence.

We are very far from believing that our philosophy alone can give us such assurance of these important truths as is requisite for our guidance and support; but we think that even our physical philosophy will point out to us the necessity of proceeding far beyond that conception of God, which represents him merely as the mind in which reside all the contrivance, law, and energy of the material world. We believe that the view of the universe which modern science has already opened to us, compared with the prospect of what she has still to do in pursuing the path on which she has just entered, will show us how immeasurably inadequate such a mode of conception would be: and that if we take into our account, as we must in reason do, all that of which we have knowledge and consciousness, and of which we have as yet no systematic science, we shall be led to a conviction that the Creator and Preserver of the material world must also contain in him such properties and attributes as imply his moral character, and as fall in

most consistently with all that we learn in any other way of his providence and holiness, his justice and mercy.

1. The sciences which have at present acquired any considerable degree of completeness, are those in which an extensive and varied collection of phenomena, and their proximate causes, have been reduced to a few simple general laws. Such are Astronomy and Mechanics, and perhaps, so far as its physical conditions are concerned, Optics. Other portions of human knowledge can be considered as perfect sciences, in any strict sense of the term, only when they have assumed this form; when the various appearances which they involve are reduced to a few principles, such as the laws of motion and the mechanical properties of the luminiferous ether. If we could trace the endless varieties of the form of crystals, and the complicated results of chemical composition, to some one comprehensive law necessarily pointing out the crystalline form of any given chemical compound, Mineralogy would become an exact science. As yet, however, we can scarcely boast of the existence of any other such sciences than those which we at first mentioned: and so far therefore as we attempt to give definiteness to our conception of the Deity, by considering him as the intelligent depositary and executor of laws of nature, we can subordinate to such a mode of conception no portion of the creation, save the mechanical movements of the universe, and the propagation and properties of light.

2. And if we attempt to argue concerning the nature of the laws and relations which govern those provinces of creation whither our science has not yet reached, by applying some analogy borrowed from cases where it has been successful, we have no chance of attaining any except the most erroneous and worthless guesses. The history of human speculations, as well as the nature of the objects of them, shows how certainly this must happen. The great generalizations which have been established in one department of our knowledge, have been applied in vain to the purpose of throwing light on the other portions which still continue in obscurity. When the Newtonian philosophy had explained so many mechanical facts, by the two great steps,—of resolving the action of a whole mass into the actions of its minutest particles, and considering these particles as centres of force,—attempts were naturally soon made to apply the same mode of explanation to facts of other different kinds. It was conceived that the whole of natural philosophy must consist in investigating the laws of force by which particles of different substances attracted and repelled, and thus produced motions, or vibrations *to* and *from* the particles. Yet what were the next great discoveries in physics? The action of a galvanic wire upon a magnet; which is not to attract or repel it, but to turn it to the *right* and *left;* to produce motion, not to or from but *transverse* to the line drawn to the acting particles; and

again, the undulatory theory of light, in which it appeared that the undulations must not be longitudinal, as all philosophers, following the analogy of all cases previously conceived, had, at first, supposed them to be, but *transverse* to the path of the ray. Here, though the step from the known to the unknown was comparatively small, when made conjecturally it was made in a direction very wide of the truth. How impossible then must it be to attain in this manner to any conception of a law which shall help us to understand the whole government of the universe!

3. Still, however, in the laws of the luminiferous ether, and of the other fluid, (if it be another fluid) by which galvanism and magnetism are connected, we have something approaching nearly to mechanical action, and, possibly, hereafter to be identified with it. But we cannot turn to any other part of our physical knowledge, without perceiving that the gulf which separates it from the exact sciences is yet wider and more obscure. Who shall enunciate for us, and in terms of what notions, the general law of *chemical* composition and decomposition? sometimes indeed we give the name of *attraction* to the affinity by which we suppose the particles of the various ingredients of bodies to be aggregated; but no one can point out any common feature between this and the attractions of which alone we know the exact effects. He who shall discover the true general law of the forces by which elements form compounds, will probably advance as far beyond the discoveries of Newton, as Newton went beyond Aristotle. But who shall say in what direction this vast flight shall be, and what new views it shall open to us of the manner in which matter obeys the laws of the Creator?

4. But suppose this flight performed;—we are yet but at the outset of the progress which must carry us towards Him. We have yet to begin to learn all that we are to know concerning the ultimate laws of organized bodies. What is the principle of *life?* What is the rule of that action of which assimilation, secretion, developement, are manifestations? and which appears to be farther removed from mere chemistry than chemistry is from mechanics. And what again is the new principle, as it seems to be, which is exhibited in *irritability* of an animal nerve? the existence of a sense? How different is this from all the preceding notions! No efforts can avoid or conceal the vast but inscrutable chasm. Those theorists, who have maintained most strennously the possibility of tracing the phenomena of animal life to the influence of physical agents, have constantly been obliged to suppose a mode of agency altogether different from any yet known in physics. Thus Lamarck, one of the most noted of such speculators, in describing the course of his researches, says, "I was soon persuaded that the *internal sentiment* constituted a power which it was necessary to take into account." And Bichat, another writer on the same

subject, while he declares his dissent from Stahl, and the earlier speculators, who had referred everything in the economy of life to a single principle, which they called the *anima* the *vital principle*, and so forth, himself introduces several principles, or laws, all utterly foreign to the region of physics; namely, *organic sensibility*, *organic contractility*, *animal sensibility*, *animal contractility*, and the like. Supposing such principles really to exist, how far enlarged and changed must our views be before we can conceive these properties, including the faculty of perception, which they imply, to be produced by the will and power of one supreme Being, acting by fixed laws. Yet without conceiving this, we cannot conceive the agency of that Deity who is incessantly thus acting in countless millions of forms and modes.

How strongly then does science represent God to us as incomprehensible; his attributes as unfathomable! His power, his wisdom, his goodness, appear in each of the provinces of nature which are thus brought before us; and in each, the more we study them, the more impressive, the more admirable do they appear. When then we find these qualities manifested in each of so many successive ways, and each manifestation rising above the preceding by unknown degrees, and through a progression of unknown extent, what other language can we use concerning such attributes than that they are *infinite?* What mode of expression can the most cautious philosophy suggest, other than that He, to whom we thus endeavour to approach, is infinitely wise, powerful, and good?

5. But with sense and consciousness the history of living things only begins. They have instincts, affections, passions, will. How entirely lost and bewildered do we find ourselves when we endeavour to conceive these faculties communicated by means of general laws! Yet they are so communicated from God, and of such laws he is the lawgiver. At what an immeasurable interval is he thus placed above everything which the creation of the inanimate world alone would imply; and how far must he transcend all ideas founded on such laws as we find there!

6. But we have still to go further and far higher. The world of reason and of morality is a part of the same creation, as the world of matter and of sense. The will of man is swayed by rational motives; its workings are inevitably compared with a rule of action; he has a conscience which speaks of right and wrong. These are laws of man's nature no less than the laws of his material existence, or his animal impulses. Yet what entirely new conceptions do they involve? How incapable of being resolved into, or assimilated to, the results of mere matter, or mere sense! Moral good and evil, merit and demerit, virtue and depravity, if ever they are the subjects of strict science, must belong to a science which views these things, not with reference to time or space, or mechanical causation, not with reference to fluid or ether, nervous irritability or corporeal

feeling, but to their own proper modes of conception; with reference to the relations with which it is possible that these notions may be connected, and not to relations suggested by other subjects of a completely extraneous and heterogeneous nature. And according to such relations must the laws of the moral world be apprehended, by any intelligence which contemplates them at all.

There can be no wider interval in philosophy than the separation which must exist between the laws of mechanical force and motion, and the laws of free moral action. Yet the tendency of men to assume, in the portions of human knowledge which are out of their reach, a similarity of type to those with which they are familiar, can leap over even this interval. Laplace has asserted that "an intelligence which, at a given instant, should know all the forces by which nature is urged, and the respective situation of the beings of which nature is composed, if, moreover, it were sufficiently comprehensive to subject these data to calculation, would include in the same *formula*, the movements of the largest bodies of the universe and those of the slightest atom. Nothing would be uncertain to such an intelligence, and the future, no less than the past, would be present to its eyes." If we speak merely of mechanical actions, this may, perhaps, be assumed to be an admissible representation of the nature of their connexion in the sight of the supreme intelligence. But to the rest of what passes in the world, such language is altogether inapplicable. A *formula* is a brief mode of denoting a rule of calculating in which numbers are to be used: and numerical measures are applicable only to things of which the relations depend on time and space. By such elements, in such a mode, how are we to estimate happiness and virtue, thought and will? To speak of a formula with regard to such things, would be to assume that their laws must needs take the shape of those laws of the material world which our intellect most fully comprehends. A more absurd and unphilosophical assumption we can hardly imagine.

We conceive, therefore, that the laws by which God governs his moral creatures, reside in his mind, invested with that kind of generality, whatever it be, of which such laws are capable; but of the character of such general laws, we know nothing more certainly than this, that it must be altogether different from the character of those laws which regulate the material world. The inevitable necessity of such a total difference is suggested by the analogy af all the knowledge which we possess and all the conceptions which we can form. And, accordingly, no persons, except those whose minds have been biassed by some peculiar habit or course of thought, are likely to run into the confusion and perplexity which are produced by assimilating too closely the government and direction of voluntary agents to the production of trains of mechanical and physical phenomena. In whatever manner voluntary and moral agency depend upon the Supreme Being, it must be in some such way that

they still continue to bear the character of will, action, and morality. And, though too exclusive an attention to material phenomena may sometimes have made physical philosophers blind to this manifest difference, it has been clearly seen and plainly asserted by those who have taken the most comprehensive views of the nature and tendency of science. "I believe," says Bacon, in his Confession of Faith, "that, at the first the soul of man was not produced by heaven or earth, but was breathed immediately from God; so that *the ways and proceedings of God with spirits are not included in nature; that is in the laws of heaven and earth;* but are reserved to the law of his secret will and grace; wherein God worketh still, and resteth not from the work of redemption, as he resteth from the work of creation; but continueth working to the end of the world." We may be permitted to observe here, that, when Bacon has thus to speak of God's dealings with his moral creatures, he does not take his phraseology from those sciences which can offer none but false and delusive analogies; but helps out the inevitable scantiness of our human knowledge, by words borrowed from a source more fitted to supply our imperfections. Our natural speculations cannot carry us to the ideas of 'grace' and 'redemption;' but in the wide blank which they leave of all that concerns our hopes of the Divine support and favour, the inestimable knowledge which revelation, as we conceive, gives us, finds ample room and appropriate place.

7. Yet even in the view of our moral constitution which natural reason gives, we may trace laws that imply a personal relation to our Creator. How can we avoid considering *that* as a true view of man's being and place, without which, his best faculties are never fully developed, his noblest energies never called out, his highest point of perfection never reached? Without the thought of a God over all, superintending our actions, approving our virtues, transcending our highest conceptions of good, man would never rise to those higher regions of moral excellence which we know him to be capable of attaining. "To deny a God," again says the great philosopher, "destroys magnanimity and the raising of human nature; for take an example of a dog, and mark what a generosity and courage he will put on, when he finds himself maintained by a man; who, to him, is instead of a God, or *melior natura:* which courage is manifestly such, as that creature, without that confidence of a better nature than his own, could never attain. So man, when he resteth and assureth himself upon divine protection and favour, gathereth a force and faith, which human nature could not obtain. Therefore, as atheism is in all respects hateful, so in this, that it depriveth human nature of the means to exalt itself above human frailty."*

Such a law, then, of reference to a Supremely Good Being, is impressed upon our nature, as the condition and means of its highest

* Bacon. Essay on Atheism.

moral advancement. And strange indeed it would be if we should suppose, that in a system where all besides indicates purpose and design, this law should proceed from no such origin; and no less inconceivable, that such a law, purposely impressed upon man to purify and elevate his nature, should delude and deceive him.

8. Nothing remains, therefore, but that the Creator, who, for purposes that even we can see to be wise and good, has impressed upon man this tendency to look to him for support, for advancement, for such happiness as is reconcileable with holiness;—to believe him to be the union of all perfection, the highest point of all intellectual and moral excellence;—is in reality such a guardian and judge, such a good, and wise, and perfect Being, as we thus irresistibly conceive him. It would indeed be extravagant to assert that the imagination of the creature, itself the work of God, can invent a higher point of goodness, of justice, of holiness, than the Creator himself possesses: that the Eternal Mind, from whom our notions of good and right are derived, is not himself directed by the rules which these notions imply.

It is difficult to dwell steadily on such thoughts. But they will at least serve to confirm the view which it was our object to illustrate; namely, how incomparably the nature of God must be elevated above any conceptions which our natural reason enables us to form; and we have been led to these reflections, it will be recollected, by following the clue of which science gave us the beginning. The Divine Mind must be conceived by us as the seat of those laws of nature which we have discovered. It must be no less the seat of those laws which we have not yet discovered, though these may and must be of a character far different from anything we can guess. The Supreme Intelligence must therefore contain the laws, each according to their true dependence, of organic life, of sense, of animal impulse, and must contain also the purpose and intent for which these powers were put into play. But the Governing Mind must comprehend also the laws of the responsible creatures which the world contains, and must entertain the purposes for which their responsible agency was given them. It must include these laws and purposes, connected by means of the notions, which responsibility implies, of desert and reward, of moral excellence in various degrees, and of well-being as associated with right doing. All the laws which govern the moral world are expressions of the thought and intentions of our Supreme Ruler. All the contrivances for moral no less than for physical good, for the peace of mind, and other rewards of virtue, for the elevation and purification of individual character, for the civilization and refinement of states, their advancement in intellect and virtue, for the diffusion of good, and the repression of evil; all the blessings that wait on perseverance and energy in a good cause; on unquenchable love of mankind, and unconquerable devotedness to truth; on purity and self-denial:

on faith, hope, and charity;—all these things are indications of the character, will, and future intentions of that God, of whom we have endeavoured to track the footsteps upon earth, and to show his handiwork in the heavens. "This God is our God, for ever and ever." And if, in endeavouring to trace the tendencies of the vast labyrinth of laws by which the universe is governed, we are sometimes lost and bewildered, and can scarce, or not at all, discern the line by which pain, and sorrow, and vice fall in with a scheme directed to the strictest right and greatest good, we yet find no room to faint or falter: knowing that these are the darkest and most tangled recesses of our knowledge; that into them science has as yet cast no ray of light; that in them reason has as yet caught sight of no general law by which we may securely hold: while, in those regions where we can see clearly, where science has thrown her strongest illumination upon the scheme of creation; where we have had displayed to us the general laws which give rise to all the multifarious variety of particular facts;—we find all full of wisdom, and harmony, and beauty: and all this wise selection of means, this harmonious combination of laws, this beautiful symmetry of relations, directed, with no exception which human investigation has yet discovered, to the preservation, the diffusion, the well-being of those living things, which, though of their nature we know so little, we cannot doubt to be the worthiest objects of the Creator's care.

THE END.

1

THE BRIDGEWATER TREATISES

ON THE

POWER, WISDOM, AND GOODNESS OF GOD, AS MANIFESTED IN THE CREATION.

TREATISE IV.

THE HAND, ITS MECHANISM AND VITAL ENDOWMENTS, AS EVINCING DESIGN.

BY SIR CHARLES BELL, K. G. H. F. R. S. L. & E.

THE HAND,

ITS MECHANISM AND VITAL ENDOWMENTS,

AS EVINCING DESIGN.

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SIR CHARLES BELL, K.G.H.F.R.S.L.&E.

A NEW EDITION

PHILADELPHIA:

CAREY, LEA & BLANCHARD.

1836.

NOTICE.

The series of Treatises, of which the present is one, is published under the following circumstances:

The Right Honourable and Reverend Francis Henry, Earl of Bridgewater, died in the month of February, 1829; and by his last Will and Testament, bearing date the 25th of February, 1825, he directed certain Trustees therein named to invest in the public funds the sum of Eight thousand pounds sterling; this sum, with the accruing dividends thereon, to be held at the disposal of the President, for the time being, of the Royal Society of London, to be paid to the person or persons nominated by him. The Testator further directed, that the person or persons selected by the said President should be appointed to write, print, and publish one thousand copies of a work *On the Power, Wisdom, and Goodness of God, as manifested in the Creation; illustrating such work by all reasonable arguments, as for instance the variety and formation of God's creatures in the animal, vegetable, and mineral kingdoms; the effect of digestion, and thereby of conversion; the construction of the hand of man, and an infinite variety of other arguments; as also by discoveries ancient and modern, in arts, sciences, and the whole extent of literature.* He desired, moreover, that the profits arising from the sale of the works so published should be paid to the authors of the works.

The late President of the Royal Society, Davies Gilbert, Esq. requested the assistance of his Grace the Archbishop of Canterbury and of the Bishop of London, in determining upon the best mode of carrying into effect the intentions of the Testator. Acting with their advice, and with the concurrence of a nobleman immediately connected with the deceased, Mr. Davies Gilbert appointed the following eight gentlemen to write separate Treatises on the different branches of the subject, as here stated:

THE REV. THOMAS CHALMERS, D. D.

PROFESSOR OF DIVINITY IN THE UNIVERSITY OF EDINBURGH.

ON THE ADAPTATION OF EXTERNAL NATURE TO THE MORAL AND INTELLECTUAL CONSTITUTION OF MAN.

JOHN KIDD, M. D. F. R. S.

REGIUS PROFESSOR OF MEDICINE IN THE UNIVERSITY OF OXFORD.

ON THE ADAPTATION OF EXTERNAL NATURE TO THE PHYSICAL CONDITION OF MAN

THE REV. WILLIAM WHEWELL, M. A. F. R. S.

FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

ON ASTRONOMY AND GENERAL PHYSICS.

SIR CHARLES BELL, K. H. F. R. S.

THE HAND: ITS MECHANISM AND VITAL ENDOWMENTS AS EVINCING DESIGN.

PETER MARK ROGET, M. D.

FELLOW OF AND SECRETARY TO THE ROYAL SOCIETY.

ON ANIMAL AND VEGETABLE PHYSIOLOGY.

THE REV. WILLIAM BUCKLAND, D. D. F. R. S.

CANON OF CHRIST CHURCH, AND PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF OXFORD.

ON GEOLOGY AND MINERALOGY.

THE REV. WILLIAM KIRBY, M. A. F. R. S.

ON THE HISTORY, HABITS, AND INSTINCTS OF ANIMALS.

WILLIAM PROUT, M. D. F. R. S.

ON CHEMISTRY, METEOROLOGY, AND THE FUNCTION OF DIGESTION.

His Royal Highness the Duke of Sussex, President of the Royal Society, having desired that no unnecessary delay should take place in the publication of the above-mentioned treatises, they will appear at short intervals, as they are ready for publication.

PREFACE.

WHEN one has to maintain an argument, he will be listened to more willingly if he is known to be unbiassed, and to express his natural sentiments. The reflections contained in these pages have not been suggested by the occasion of the Bridgewater Treatises, but arose, long ago, in a course of study, directed to other objects. An anatomical teacher, who is himself aware of the higher bearings of his science, can hardly neglect the opportunity which the demonstrations before him afford, of making an impression upon the minds of those young men who, for the most part, receive the elements of their professional education from him; and he is naturally led to indulge in such trains of reflection, as will be found in this essay.

So far back as the year 1813, the late excellent vicar of Kensington, Mr. Rennell, attended the author's lectures, and found him engaged in maintaining the principles of the English school of Physiology, and in exposing the futility of the opinions of those French philosophers and physiologists, who represented life as the mere physical result of certain combinations and actions of parts, by them termed Organization.

That gentleman thought that the subject admitted of an argument which it became him to use, in his office of "Christian Advocate."* This will show the reader that the sentiments and the views, which a sense of duty to the young men about him induced the author to deliver, and which Mr. Rennell heard only by accident, arose naturally out of those studies.

It was at the desire of the Lord Chancellor that the author wrote the essay on "Animal Mechanics;" and it was probably from a belief that the author felt the importance of the subjects touched upon in that essay, that his lordship was led to do him the further

* An office in the University of Cambridge.

honour of asking him to join with him in illustrating the "Natural Theology" of Dr. Paley.

That request was especially important, as showing, that the conclusions, to which the author had arrived, were not the peculiar or accidental suggestions of professional feeling, nor of solitary study, which is so apt to lead to enthusiasm, but that the powerful and masculine mind of Lord Brougham was directed to the same object: that he, who in early life was distinguished for his successful prosecution of science, and who has never forgotten her interests amidst the most arduous and active duties of his high station, encouraged and partook of these sentiments.

Thus, from at first maintaining that design and benevolence were every where visible in the natural world, circumstances have gradually drawn the author to support these opinions more ostentatiously and elaborately than was his original wish.

The author cannot conceal from himself the disadvantages to which he is exposed in coming before the public, not only with a work, in some measure extra-professional, but with associates, distinguished by classical elegance of style, as well as by science. He must entreat the reader to remember that he was, early and long, devoted to the study of anatomy; and with a feeling (right or wrong) that it surpassed all other studies, in interest and usefulness. This made him negligent of those acquirements which would have better fitted him for the honourable association in which he has been placed: and no one can feel more deeply that the suggestions which occur in the intervals of an active professional life, must always be unfavourably contrasted with what comes of the learned leisure of a College.

The author has to acknowledge his obligation to Davies Gilbert, Esq. late President of the Royal Society, for having assigned to him a task of so much interest. When he undertook it, he thought only of the pleasure of pursuing these investigations, and perhaps too little of what the public were entitled to expect from an Essay composed in circumstances so peculiar, and forming a part in "this great argument."

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THE HAND,

ITS MECHANISM AND VITAL ENDOWMENTS,

AS EVINCING DESIGN.

CHAPTER I.

If we contemplate any natural object, especially any part of animated nature, fully and in all its bearings, we can arrive only at this conclusion: that there is design in the mechanical construction, benevolence shown in the living properties, and that good predominates: we shall perceive that the sensibilities of the body have a relation to the qualities of things external, and that delicacy of texture is a necessary consequence of this relation.

Wonderful, and exquisitely constructed, as the mechanical appliances are for the protection of this delicate structure, they are altogether insufficient; and a protection of a very different kind, which shall animate the body to the utmost exertion, is requisite for safety. Pain, whilst it is a necessary contrast to its opposite pleasure, is the great safeguard of the frame. Finally, as to man, we shall be led to infer that the pains and pleasures of mere bodily sense (with yet more benevolent intention) carry us onward, through the developement and improvement of the mind itself, to higher aspirations.

Such is the course of reasoning which I propose to follow in giving an account of the hand and arm, contrasting them with the corresponding parts of living creatures, through all the divisions of the chain of vertebrated animals.

When I first thought of extending my notes on this subject, it appeared to me that I might have many other topics more prolific in proofs of design, and more interesting; but I now find that there is no end to illustration, and that the subject branches out interminably.

Some may conceive that as I have for my title the Human Hand, and the relation of the solid structures of the animal frame, it will lead me to consider the body as a machine only. I neither see the necessity for this, nor do I acknowledge the danger of considering it in that light. I embark fearlessly in the investigation, convinced that, yielding to the current of thought, and giving the fullest scope to inquiry, there can be no hidden danger if the mind be free from vicious bias. I cannot see how scepticism should arise out of the contemplation of the structure and mechanism of the animal body.

Let us for a moment think what is the natural result of examining the human body as a piece of machinery, and let us see whether it makes the creation of man more or less important in his relation to the whole scheme of nature.

Suppose that there is placed before us a machine for raising great weights, be it the simplest of all, the wheel and axle. We are given to understand that this piece of mechanism has the property of multiplying the power of the hand. But a youth of subtile mind may say, I do not believe that it is possible so to multiply the power of the hand; and if the mechanician be a philosopher, he will rather applaud the spirit of doubt. If he condescend to explain, he will say, that the piles driven into the ground, or the screws which unite the machinery to the beams, are the fixed points which resist in the working of the machine; that their resistance is a necessary condition, since it is thrown, together with the power of the hand, on the weight to be raised. And he will add that the multiplication of wheels does not alter the principle of action, which every one may see in the simple lever, to result from the resistance of the fulcrum or point, on which it rests.

Now grant that man's body is a machine, where are the points of resistance? are they not in the ground he stands upon? This leads us to inquire by what property we stand. Is it by the weight of the body, or in other words, is it by the attraction of the earth? The terms attraction, or gravitation, lead at once to the philosophy of the question. We stand because the body has weight, and a resistance, in proportion to the matter of the animal frame, and the magnitude of the globe itself. We wait not at present to observe the adjustment of the strength of the frame, the resistance of the bones, the elasticity of the joints, and the power of the muscles to the weight of the whole. Our attention is directed to the relations which the frame has to the earth we are placed upon.

Some philosophers, who have considered the matter curiously, have said, that if man were translated bodily to another planet, and were it smaller than the earth, he would be too light, and he would walk like one wading in deep water. If the planet were larger, the attraction of his body would make him feel as if his limbs

were loaded with lead; nay, the attraction might be so great as to destroy the fabric of the body, crushing bones and all.*

However idle these fancies may be, there is no doubt that the animal frame is formed with a due relation to the earth we inhabit, and that the parts of the animal body, and we may say the strength of the materials, have as certainly a correspondence with the weight, as the wheels and levers of a machine, or the scaffolding which sustains them, have relative to the force and velocity of the machinery, or the load that they are employed to raise.

The mechanism and organization of animals have been often brought forward for a different purpose from that for which I use them. We find it said, that it is incomprehensible that an all-powerful Being should manifest his will in this manner; that mechanical contrivance implies difficulties overcome: and how strange it is, they add, that the perceptions of the mind, which might have been produced by some direct means, or have arisen spontaneously, are received through an instrument so fine and complex as the eye; —and which requires the creation pf the element of light, to enter the organ and to cause vision.

For my own part, I think it most natural to contemplate the subject quite differently. We perhaps presume too much, when we say, that light has been created for the purpose of vision. We are hardly entitled to pass over its properties as a chemical agent, its influence on the gases, and, in all probability on the atmosphere, its importance to vegetation, to the formation of the aromatic and volatile principles, and to fructification, its influence on the animal surface by invigorating the circulation, and imparting health. In relation to our present subject, it seems more rational to consider light as second only to attraction, in respect to its importance in nature, and as a link connecting systems of infinite remoteness.

To have a conception of this we must tutor our minds, and acquire some measure of the velocity of light, and of the space which it fills. It is not sufficient to say that it moves 200,000 miles in a second; for we can comprehend no such degree of velocity. If we are further informed that the earth is distant from the sun 95,000,000 of miles, and that light traverses the space in 8 minutes and 1-8th, it is but another way of affirming the inconceivable rapidity of its transmission. Astronomers, the power of whose mind affords us the very highest estimate of human faculties, the accuracy of whose calculations is hourly visible to us, have affirmed that light emanates from celestial bodies at such vast distance, that thousands of years shall elapse during its progress to our earth: yet matter impelled by a force equal to its transmission

* The matter of Jupiter is as 330,600 to 1000 of our Earth. The diameter of Pallas is 80 miles; the Earth is 7,911 miles in diameter.

through this space, shall enter the eye, and strike upon the delicate nerve with no other effect than to produce vision.

Instead of saying that light is created for the eye, and to give us the sense of vision, is it not more conformable to a just manner of considering these things that our wonder and our admiration should fix on the fact, that this small organ, the eye, is formed with relation to a creation of such vast extent and grandeur:—and more especially, that the ideas arising in the mind through the influence of that matter and this organ, are constituted a part of this vast whole!

By such considerations we are led to contemplate the human body in its different relations. The magnitude of the earth determines the strength of our bones, and the power of our muscles; so must the depth of the atmosphere determine the condition of our fluids, and the resistance of our blood vessels; the common act of breathing, the transpiration from the surfaces, must bear relation to the weight, moisture, and temperature of the medium which surrounds us. A moment's reflection on these facts proves to us that our body is formed with a just correspondence to all these external influences.

These views leads us to another consideration, that the complexity of our structure belongs to exernal nature, and not of necessity to the mind. Whilst man is an agent in a material world, and sensible to the influence of things external, complexity of structure is a necessary part of his constitution. But we do not perceive a relation between this complexity and the mind. From aught that we learn by this mode of study, the mind may be as distinct from the bodily organs as are the exterior influences which give them exercise.

Something, then, we observe to be common to our planet and to others, to our system, and to other systems; matter, attraction, light; which nearly implies that the mechanical and chemical laws must be the same throughout. It is perhaps too much to affirm, with an anonymous author, that an inhabitant of our world would find himself at home in any other, that he would be like a traveller only, for a moment perplexed by diversity of climate and strangeness of manners, and confess, at last, that nature was everywhere and essentially the same. However this may be, all I contend for is, the necessity of certain relations being established between the planet and the frames of all which inhabit it; between the great mass and the physical properties of every part; that in the mechanical construction of animals, as in their endowments of life, they are created in relation to the whole, planned together and fashioned by one Mind.

The passiveness which is natural in infancy, and the want of reflection as to the sources of enjoyment which is excusable in

youth, become insensibility and ingratitude in riper years. In the early stages of life, before our minds have the full power of comprehension, the objects around us serve but to excite and exercise the outward senses. But in the maturity of reason, philosophy should present these things to us anew, with this difference, that the mind may contemplate them; that mind which is now strengthened by experience to comprehend them, and to entertain a grateful sense of them.

It is this sense of gratitude which distinguishes man. In brutes, the attachment to offspring for a limited period is as strong as in him, but it ceases with the necessity for it. In man, on the contrary the affections continue, become the sources of all the endearing relations of life, and the very bonds by which society is connected.

If the child, upon the parent's knee, is unconsciously incurring a debt, and strong affections grow up so naturally that nothing is more universally condemned than filial ingratitude, we have but to change the object of affection, to find the natural source of religion itself. We must show that the care of the most tender parent is in nothing to be compared with those provisions for our enjoyment and safety, which it is not only beyond the ingenuity of man to provide, but which he can hardly comprehend, while he profits by them.

If man, of all living creatures, be alone capable of gratitude, and through this sense be capable also of religion, the transition is natural; since the gratitude due to parents is abundantly more owing to Him "who saw him in his blood, and said, Live."

For the continuance of life, a thousand provisions are made. If the vital actions of a man's frame were directed by his will, they are necessarily so minute and complicated, that they would immediately fall into confusion. He cannot draw a breath, without the exercise of sensibilities as well ordered as those of the eye or ear. A tracery of nervous cords unites many organs in sympathy, of which, if one filament were broken, pain and spasm, and suffocation would ensue. The action of his heart, and the circulation of his blood, and all the vital functions are governed through means and by laws which are not dependent on his will, and to which the powers of his mind are altogether inadequate. For had they been under the influence of his will, a doubt, a moment's pause of irresolution, a forgetfulness of a single action at its appointed time, would have terminated his existence.

Now, when man sees that his vital operations could not be directed by reason—that they are constant, and far too important to be exposed to all the changes incident to his mind, and that they are given up to the direction of other sources of motion than the will, he acquires a full sense of his dependence. If man be fretful and wayward, and subject to inordinate passion, we perceive the benevolent design in withdrawing the vital motions from the in-

fluence of such capricious sources of action, so that they may neither be disturbed like his moral actions, nor lost in a moment of despair.

Ray, in speaking of the first drawing of breath, delivers himself very naturally: "Here, methinks, appears a necessity of bringing in the agency of some superintendant intelligent being, for what else should put the diaphragm and the muscles serving respiration in motion all of a sudden so soon as ever the fœtus is brought forth? Why could they not have rested as well as they did in the womb? What aileth them that they must needs bestir themselves to get in air to maintain the creature's life? Why could they not patiently suffer it to die? You will say the spirits do at this time flow to the organs of respiration, the diaphragm, and other muscles which concur to that action and move them. But what raises the spirits which were quiescent, &c., I am not subtile enough to discover."

We cannot call this agency, a new intelligence different from the mind, because, independently of consciousness, we can hardly so define it. But there is bestowed a sensibility, which being roused (and it is excited by the state of the circulation,) governs these muscles of respiration, and ministers to life and safety, independently of the will.

When man thus perceives, that in respect to all these vital operations he is more helpless than the infant, and that his boasted reason can neither give them order nor protection, is not his insensibility to the Giver of these secret endowments worse than ingratitude? In a rational creature, ignorance of his condition becomes a species of ingratitude; it dulls his sense of benefits, and hardens him into a temper of mind with which it is impossible to reason, and from which no improvement can be expected.

Debased in some measure by a habit of inattention, and lost to all sense of the benevolence of the Creator, he is roused to reflection only by overwhelming calamities, which appear to him magnified and disproportioned; and hence arises a conception of the Author of his being more in terror than in love.

There is inconsistency and something of the child's propensities still in mankind. A piece of mechanism, as a watch, a barometer, or a dial, will fix attention—a man will make journeys to see an engine stamp a coin, or turn a block; yet the organs through which he has a thousand sources of enjoyment, and which are in themselves more exquisite in design and more curious both in contrivance and in mechanism, do not enter his thoughts; and if he admire a living action, that admiration will probably be more excited by what is uncommon and monstrous, than by what is natural and perfectly adjusted to its office—by the elephant's trunk, than by the human hand. This does not arise from an unwillingness to contemplate the superiority or dignity of our own nature, nor from an incapacity of admiring the adaptation of parts. It is the effect of habit. The hu-

man hand is so beautifully formed, it has so fine a sensibility, that sensibility governs its motions so correctly, every effort of the will is answered so instantly, as if the hand itself were the seat of that will; its actions are so powerful, so free, and yet so delicate, that it seems to possess a quality instinct in itself, and there is no thought of its complexity as an instrument, or of the relations which make it subservient to the mind; we use it as we draw our breath, unconsciously, and have lost all recollection of the feeble and ill-directed efforts of its first exercise, by which it has been perfected. Is it not the very perfection of the instrument which makes us insensible to its use? A vulgar admiration is excited by seeing the spider-monkey pick up a straw, or a piece of wood, with its tail; or the elephant searching the keeper's pocket with his trunk. Now, fully to examine the peculiarity of the elephant's structure, that is to say, from its huge mass, to deduce the necessity for its form, and from the form the necessity for its trunk, would lead us through a train of very curious observations, to a more correct notion of that appendage, and therefore to a truer admiration of it. But I take this part in contrast with the human hand, merely to show how insensible we are to the perfections of our own frame, and to the advantages attained through such a form. We use the limbs without being conscious, or, at least, without any conception of the thousand parts which must conform to a single act. To excite our attention, we must either see the actions of the human frame performed in some mode, strange and unexpected, such as may raise the wonder of the ignorant and vulgar; or by an effort of the cultivated mind, we must rouse ourselves to observe things and actions, of which, as we have said, the sense has been lost by long familiarity.

In the following essay, I shall take up the subject comparatively, and exhibit a view of the bones of the arm, descending from the human hand to the fin of the fish. I shall in the next place review the actions of the muscles of the arm and hand; then proceeding to the vital properties, I shall advance to the subject of sensibility, leading to that of touch; afterwards, I shall show the necessity of combining the muscular action with the exercise of the senses, and especially with that of touch, to constitute in the hand what has been called the geometrical sense.

I shall describe the organ of touch, the cuticle and skin, and arrange the nerves of the hand according to their functions. I shall then inquire into the correspondence between the capacities and endowments of the mind, in comparison with the external organs, and more especially with the properties of the hand; and conclude by showing that animals have been created with a reference to the globe they inhabit; that all their endowments and various organization bear a relation to their state of existence, and to the elements around them; that there is a plan universal, extending through all animated nature, and which has prevailed in the earliest condition

of the world; and that, finally, in the most minute or most comprehensive study of those things we every where see prospective design.

CHAPTER II.

We ought to define the hand as belonging exclusively to man—corresponding in sensibility and motion with that ingenuity which converts the being who is the weakest in natural defence, to the ruler over animate and inanimate nature.

If we describe the hand as that extremity which has the thumb and fingers opposed to each other, so as to form an instrument of prehension, we extend it to the quadrumana or monkeys. But the possession of four hands by animals of that class implies that we include the posterior as well as the anterior extremities. Now the anterior extremity of the monkey is as much a foot as the posterior extremity is a hand; both are calculated for their mode of progression, climbing, and leaping from the branches of trees, just as the tail in some species is converted into a hand, and is as useful an instrument of suspension as any of the four extremities.*

The armed extremities of a variety of animals give them great advantages; but if man possessed any similar provisions, he would forfeit his sovereignty over all. As Galen, long since, observed, "did man possess the natural armour of the brutes, he would no longer work as an artificer, nor protect himself with a breast-plate, nor fashion a sword or spear, nor invent a bridle to mount the horse and hunt the lion. Neither could he follow the arts of peace, construct the pipe and lyre, erect houses, place altars, inscribe laws, and through letters hold communion with the wisdom of antiquity:"—"*tibique liceat literarum et manuum beneficiis etiam nunc colloqui cum Platone, cum Aristotele, cum Hippocrate.*"

But the hand is not a distinct instrument; nor is it properly a su-

* The Coaita, or Spider Monkey, so called from the extraordinary length of its extremities, and its motions. The tail answers all the purposes of a hand, and the animal throws itself about from branch to branch, sometimes swinging from the foot, sometimes by the hand, but oftener and with a greater reach by the tail. The prehensile part of the tail is covered only with skin, forming an organ of touch, as discriminating as the hand. The Caraya, or black howling monkey of Cumana, when shot, is found suspended by its tail, round a branch. Naturalists have been so struck with the property of the tail of the Ateles, as to compare it with the proboscis of the elephant; they have assured us that they fish with it.

The most interesting use of the tail is seen in the Opossum. The young of that animal entwine their tails around their mother's tail and mount upon her back, where they sit secure, while she escapes from her enemies.

peradded part. The whole frame must conform to the hand, and act with reference to it. Our purpose will not be answered by examining it alone; we must extend our views to all those parts of the body which are in strict connection with the hand. For example, the bones from the shoulder to the finger ends, have that systematic arrangement which makes it essential to examine the whole extremity; and in order fully to comprehend the fine arrangement of the parts, which is necessary to the motions of the fingers, we must also compare the structure of the human body with that of other animals.

Were we to limit our inquiry to the bones of the arm and hand in man, no doubt we should soon discover their provisions for easy, varied, and powerful action; and conclude that nothing could be more perfectly suited to their purposes. But we must extend our views to comprehend a great deal more,—a greater design.

By a skeleton, is understood the system of bones, which being internal, gives the characteristic form to the animal, and receives the action of the exterior muscles. This system belongs, however, only to one part of the animal kingdom, that higher division,—the animalia vertebrata, which includes the whole chain of beings, from man to fishes.

The function of the greatest consequence to life is respiration; and the mode in which this is performed, that is to say, the manner in which the decarbonization of the blood is effected through its exposure to the atmosphere, produces a remarkable change in the whole frame-work of the animal body.

Man, the mammalia, birds, reptiles, and fishes have much of the mechanism of respiration in common; and there is a resemblance through them all, in the texture of the bones, in the action of the muscles, and in the arrangement of the nerves. They all possess the vertebral column or spine; and the existence of this column, not only implies an internal skeleton, but that particular frame-work of ribs, which is suited to move in breathing. But the ribs do not move of themselves, they must have appropriate muscles; and these muscles must have their appropriate nerves; and for supplying these nerves there must be a spinal marrow. The spinal canal is as necessary to the spinal marrow as the skull is to the brain. So that we come round to understand the necessity of a vertebra, to the formation of the spinal marrow; and the reader may comprehend how much enters into the conception of the anatomist or naturalist, when the term is used, a vertebrated animal, viz:—an internal skeleton, a particular arrangement of respiratory organs, and a conformity in the nervous system.

It is to this superior division that I shall limit myself, in making a review of the bones of the upper extremity.

Were I to indulge in the admiration naturally arising out of this subject, and point out the strength and the freedom of motion in the

upper extremity at the ball and socket joint of the shoulder,—the firmness of the articulation of the elbow, and yet how admirably it is suited to the co-operation of the hands,—the fineness of the motion of the hand itself, divided among the joints of twenty-nine bones, it might be objected to with some show of reason; and it might be said, the bones and the forms of the joints which you are admiring, are so far from being peculiarly suited to the hand of man, that they may be found in any other vertebrated animal.

But this would not abate our admiration, it would only induce us to take a more comprehensive view of nature, and remind us that our error was in looking at a part only, instead of embracing the whole system; where by slight changes and gradations hardly perceptible, the same bones are adjusted to every condition of animal existence.

We recognise the bones which form the upper extremity of man, in the fin of the whale, in the paddle of the turtle, and in the wing of the bird. We see the same bones, perfectly suited to their purpose, in the paw of the lion or the bear, and equally fitted for motion in the hoof of the horse, or in the foot of the camel, or adjusted for climbing or digging in the long clawed feet of the sloth or bear.

It is obvious, then, that we should be occupied with too limited a view of our subject, were we to consider the human hand in any other light than as presenting the most perfect combination of parts: as exhibiting the parts, which in different animals are suited to particular purposes, so combined in the hand, as to perform actions the most minute and complicated, consistently with powerful exertion.

The wonder still is, that whether we examine this system in man, or in any of the inferior species of animals, nothing can be more curiously adjusted or appropriated; and we should be inclined to say, whatever instance occupied our thoughts for the time, that to this particular object the system had been framed.

The view which the subject opens to us, is unbounded. The curious synthesis by which we ascertain the nature, condition, and habits of an extinct animal, from the examination of its fossil remains, is grounded on a knowledge of the system of which we are speaking. A bone consists of many parts; but for our present purpose it is only necessary to observe that the hard substance, the phosphate of lime, which we familiarly recognise as bone, is everywhere penetrated by membranes and vessels as delicate as those which belong to any other part of the body. Some bones are found with their animal part remaining, others are fossilized. The phosphate of lime loses its phosphoric acid, and the earth of bone remains incorruptible, while the softer animal matter undergoes the process of decomposition, and is dissipated. The bone in this condition may become fossilized; silicious earth, or lime in composition with iron, or iron pyrites, may pass by infiltration into the interstices of the original earthy matter, and in this state it is as permanent as

the solid rock. It retains the form, though not the internal structure of bone; and that form, in consequence of the perfect system which we have hinted at, becomes a proof of revolutions the most extraordinary. The mind of the inquirer is carried back, not merely to the contemplation of animal structure, but by inference, from the system of animal organization to the structure of the globe itself.

The bones of large animals and in great variety are found imbedded in the surface of the earth. They are discovered in the beds of rivers, they are found where no waters flow, they are dug up from under the solid limestone rock. The bones thus exposed, become naturally a subject of intense interest, and are unexpectedly connected with the inquiry in which we are engaged. Among other important conclusions they lead to this—that there is not only a scheme or system of animal structure pervading all the classes of animals which inhabit the earth, but that the principle of this great plan of creation was in operation, and governed the formation of those animals which existed previous to the revolutions that the earth itself has undergone: that the excellence of form now seen in the skeleton of man, was in the scheme of animal existence long previous to the formation of man, and before the surface of the earth was prepared for him or suited to his constitution, structure, or capacities.

A skeleton is dug up which has lain under many fathoms of rock: being the bones of an animal which lived antecedent to that formation of rock, and at a time when the earth's surface must have been in a condition very different from what it is now. These remains prove, that all animals have been formed of the same elements, and have had analogous organs—that they received new matter by digestion, and were nourished by means of a circulating fluid—that they possessed feeling through a nervous system, and were moved by the action of muscles—that their organs of digestion, circulation, and respiration were modified by circumstances, as in the animals now alive, and in accordance with their habits and modes of living. The changes in the organs are but variations in the great system by which new matter is assimilated to the animal body,—and however remarkable these may be, they always bear a certain relation to the original type as parts of the same great design.

In examining these bones of the ancient world, so regularly are they formed on the same principle which is evident in the animals now inhabiting the earth, that on observing their shape, and the processes by which their muscles were attached, we can reduce the animals to which they belonged, to their orders, genera, and species, with as much precision as if the recent bodies had been submitted to the eye of the anatomist. Not only can we demonstrate that their feet were adapted to the solid ground, or to the oozy bed of rivers,—for speed, or for grasping and tearing; but judging by these indications of the habits of the animals, we acquire a knowledge of the

condition of the earth during their period of existence; that it was suited at one time to the scaly tribe of the lacertæ, with languid motion; at another, to animals of higher organization, with more varied and lively habits; and finally we learn, that at any period previous to man's creation, the surface of the earth would have been unsuitable to him.

On comparing some of the present races of animals, with the fossil remains of individuals of the same family, some singular opinions on their imperfections have been expressed by Buffon, and adopted by Cuvier. The animals I allude to are of the tardigrade family; the Ai,* in which, as they believe, the defect of organization is the greatest; and the Unau, † which they consider only a little less miserably provided for existence.

Modern travellers express their pity for these animals: whilst other quadrupeds, they say, range in boundless wilds, the sloth hangs suspended by his strong arms—a poor ill-formed creature, deficient as well as deformed, his hind legs too short, and his hair like withered grass; his looks, motions, and cries conspire to excite pity; and, as if this were not enough, they say that his moaning makes the tiger relent and turn away. This is not a true picture: the sloth cannot walk like quadrupeds, but he stretches out his strong arms,—and if he can hook on his claws to the inequalities of the ground, he drags himself along. This is the condition which authorizes such an expression as "the bungled and faulty composition of the sloth." But when he reaches the branch or the rough bark of a tree, his progress is rapid; he climbs hand over head, along the branches till they touch, and thus from bough to bough, and from tree to tree; he is most alive in the storm, and when the wind blows, and the trees stoop, and the branches wave and meet, he is then upon the march.

The compassion expressed by these philosophers for animals,‡ which they consider imperfectly organized, is uncalled for; as well might they pity the larva of the summer fly, which creeps in the bottom of a pool, because it cannot yet rise upon the wing. As the insect has no impulse to fly until the metamorphosis is perfect, and the wings developed, so we have no reason to suppose that a disposition or instinct is given to animals, where there is no corresponding provision for motion.

The sloth may move tardily on the ground, his long arms and his preposterous claws may be an incumbrance, but they are of advantage in his natural place, among the branches of trees, in obtaining his food, and in giving him shelter and safety from his enemies.

* Bradypus Tridactylus:—bradypus (*slow-footed,*) tridactylus (*three-toed,*) of the order Edentata (*wanting incisor teeth.*)

† Bradypus didactylus.

‡ The subject is pursued in the end of the following chapter.

We must not estimate the slow motions of animals by our own sensations. The motion of the bill of the swallow, or the fly-catcher, in catching a fly, is so rapid that we do not see it, but only hear the snap. On the contrary, how very different are the means given to the chamelion for obtaining his food; he lies more still than the dead leaf, his skin is like the bark of the tree, and takes the hue of surrounding objects. Whilst other animals have excitement conforming to their rapid motions, the shrivelled face of the chamelion hardly indicates life; the eyelids are scarcely parted; he protrudes his tongue with a motion so imperceptible towards the insect, that it is touched and caught more certainly than by the most lively action. Thus, various creatures living upon insects, reach their prey by different means and instincts; rapidity of motion, which gives no time for escape, is bestowed on some, while others have a languid and slow movement that excites no alarm.

The loris, a tardigrade animal, might be pitied too for the slowness of its motions, if they were not the very means bestowed upon it as necessary to its existence. It steals on its prey by night, and extends its arm to the bird on the branch, with a motion so imperceptibly slow, as to make sure of its object.* Just so, the Indian perfectly naked, his hair cut short, and his skin oiled, creeps under the canvass of the tent, and moving like a ghost, stretches out his hand, with so gentle a motion as to displace nothing, and to disturb not even those who are awake and watching. Against such thieves, we are told, that it is hardly possible to guard; and thus, the necessities or vicious desires of man subjugate him, and make him acquire, by practice, the wiliness which is implanted as instinct in brutes; or we may say that in our reason we are brought to imitate the irrational creatures, and so to vindicate the necessity for their particular instincts, of which every class affords an instance. We have examples in insects, as striking as in the loris or the chamelion. Evelyn describes the actions of the spider (*aranea scenica*) as exhibiting remarkable cunning in catching a fly. "Did the fly, (he says,) happen not to be within a leap, the spider would move towards it, so softly, that its motion seemed not more perceptible than that of the shadow of the gnomon of a dial."†

* For our purpose, it may be well to notice other characters of this and similar animals which prowl by night. They are inhabitants of the tropical regions. Now, the various creatures which enliven the woods in the day-time, in these warm climates, have fine skins, and smooth hair; but those have a coat like animals of the arctic regions. What is this, but to clothe them, as the sentinel is clothed, whose watch is in the night. They have eyes too, which, from their peculiarity, are called nocturnal, being formed to admit a greater pencil of rays. For this purpose the globe is large and prominent, and the iris contractile, to open the pupil to the greatest extent.—We have seen how all their motions and instincts correspond with their nocturnal habits.

† The passage continues—"if the intended prey moved, the spider would keep pace with it exactly as if they were actuated by one spirit, moving backwards, for-

I would only remark further on these slow motions of the muscles of animals; that we are not to account this a defect, but rather an appropriation of muscular power. Since in some animals the same muscles which move their members in a manner to be hardly perceptible, can at another time act with the velocity of a spring.

Now Buffon, speaking of the extinct species of the tardigrade family, considers them as monsters by defect of organization; as attempts of nature in which she has failed to perfect her plan; that she has produced animals which must have lived miserably, and which are effaced as failures from the list of living beings. The Baron Cuvier does not express himself more favourably, when he says of the existing species, that they have so little resemblance to the organization of animals generally, and their structure is so much in contrast with that of other creatures, that he could believe them to be the remnants of an order unsuitable to the present system of nature; and if we are to look for their congeners, it must be in the interior of the earth, in the ruins of the ancient world.

The animals of the Antediluvian world were not monsters; there was no lusus or extravagance. Hideous as they appear to us, and like the phantoms of a dream, they were adapted to the condition of the earth when they existed. I could have wished that our naturalists had given the inhabitants of that early condition of the globe, names less scholastic. We have the plesiosaurus and plesiosaurus dolichodeirus, we have the ichthyosaurus and megalosaurus, and iguanodon, pterodactyles, with long and short beaks, tortoises, and crocodiles; and these are found among reeds and grasses of gigantic proportions, algæ and fuci, and a great variety of mollusca of inordinate bulk, compared with those of the present day, as ammonites and nautili. Every thing declares, that these animals inhabited shallow seas, and estuaries, or great inland lakes: that the surface of the earth did not rise up in peaks and mountains, or that perpendicular rocks bound in the seas; but that it was flat, slimy, and covered with a loaded and foggy atmosphere. There is, indeed, every reason to believe that the classes mammalia and birds were not then created, and that if man had been placed in this condition of the earth, there must have been around him a state of things unsuited to his constitution, and not calculated to call forth his capacities.

But looking to the class of animals as we have enumerated them, there is a correspondence; they were scaly; they swam in water, or crept upon the margins; there were no animals possessed of ra-

wards, or on each side without turning. When the fly took wing, and pitched itself behind the huntress, she turned round with the swiftness of thought, and always kept her head towards it, though to all appearance as immoveable as one of the nails driven into the wood on which was her station; till at last, being arrived within due distance, swift as lightning she made the fatal leap, and secured her prey."—Evelyn, as quoted by Kirby and Spence.

pidity of motion, and no birds of prey to stoop upon them; there was, in short, that balance of the power of destruction and of self preservation, which we see now to obtain in higher animals since created, with infinitely varied instincts and powers for defence or attack.

It is hardly possible to watch the night and see the break of day in a fine country, without being sensible that our pleasantest perceptions refer to the scenery of nature, and that we have feelings in sympathy with every successive change, from the first streak of light, until the whole landscape is displayed in valleys, woods, and sparkling waters; and the changes on the scene are not more rapid than the transitions of the feelings which accompany them. All these sources of enjoyment, the clear atmosphere and the refreshing breezes, are as certainly the result of the several changes which the earth's surface has undergone, as the displaced strata within its crust are demonstrative of these changes. We have every reason to conclude that these revolutions, whether they have been slowly accomplished and progressively or by sudden, vast and successive convulsions, were necessary to prepare the earth for that condition which should correspond with the faculties to be given to man, and be suited to the full exercise of his reason, as well as to his enjoyment.

If a man contemplate the common objects around him—if he observe the connexion between the qualities of things external and the exercise of his senses, between the senses so excited, and the condition of his mind, he will perceive that he is in the centre of a magnificent system, and that the strictest relation is established between the intellectual capacities and the material world.

In the succeeding chapter we shall take a comparative view of the anatomy of the arm, and we shall be led to observe some very extraordinary changes, as we trace the same parts through different genera and species of animals. In doing this, we are naturally called upon to notice certain opinions which prevail on the subject.

We have already hinted, that geologists have discovered, that in the stratified rocks there is proof of a regular succession of formations in the crust of the earth, and that animals of very different structure have been imbedded, and are preserved in them. In the earlier formed strata animals are found which are low, as we choose to express it, in the chain of existence; in higher strata, oviparous animals of great bulk, and more complex structure, are discovered; above the strata containing these oviparous reptiles, there are found mammalia; and in the looser and more superficial stratum are the bones of the mastodon, megatherium, rhinoceros, and elephant, &c. We must add that geologists agree that man has been created last of all.

Upon these facts, a theory is raised, that there has been a succession of animals gradually increasing in the perfection of their structure; that the first impulse of nature was not sufficient to the pro-

duction of the highest and most perfect, and that it was only in her mature efforts that mammalia were produced. We are led to this reflection: that the creation of a living animal, the bestowing of life on a corporeal frame, however simple the structure of that body, is of itself an act of creative power so conceivably great, that we can have no title to presume that the change in the organization, such as the provision of bones and muscles, or the production of new organs of sense, is a higher effort of that power. We have a better guide in exploring the varieties of animated nature, when we acknowledge the manifest design with which all is accomplished; the adaptation of the animals, their size, their economy, their organs, and instruments to their condition.

Whether we make the most superficial or most profound examination of animals in their natural state, we shall find that the varieties are so balanced as to ensure the existence of all. This, we think, goes far to explain, first, why the remains of certain animals are found in certain strata which imply a peculiar condition of the earth's surface; and, secondly, why these animals are found grouped together. For, as we may express it, if there had been an error in the grouping, there must have been a destruction of the whole; the balance which is necessary to their existence having been destroyed. We know very well that so minute a thing as a fly, will produce, in twenty-four hours, millions, which, if not checked, will ere long darken the air, and render whole regions desolate; so that if the breeze does not carry them in due time into the desert, or into the ocean, the destruction will be most fearful.

As in the present day every creature has its natural enemy; or is checked in production, sometimes by a limited supply of food, sometimes by disease, or by the influence of seasons; and as in the whole a balance is preserved, we may reasonably apply the same principle in explanation of the condition of things as they existed in the earlier stages of the world's progress; certainly, this view is borne out, by what we have as yet discovered in the grouping of animals, in the different stratifications or deposites of the earth.

If the naturalist or geologist, exploring the rocks of secondary formation, should find inclosed within them animals of the class Molusca, it agrees with his preconceived notions, that only animals of their simple structure were in existence, at the time of the subsidence of that matter of which the rock consists. But if the spine of a fish, or a jawbone, or a tooth, be discovered, he is much disturbed, because, here is the indication of an animal having been at that time formed on a different type,—on that plan which belongs to animals of a superior class.—Whereas on the supposition that animals are created with that relation to circumstances, which we have just alluded to, it would only imply that certain animals, which had hitherto increased undisturbed, had arrived at a period, when their numbers were to be limited; or that the condition of the ele-

ments and the abundance of food were now suited to the existence of a species of the vertebrata.

The principle then, in the application of which we shall be borne out, is, that there is an adaptation, an established and universal relation between the instincts, organization, and instruments of animals on the one hand, and the element in which they are to live, the position which they hold, and their means of obtaining food on the other;—and this holds good with respect to the animals which have existed, as well as those which now exist.

In discussing this subject of the progressive improvement of organized beings, it is affirmed that the last created of all, man, is not superior in organization to the others, and that if deprived of intellectual power he is inferior to the brutes. I am not arguing to support the gradual developement and improvement of organization; but, however indifferent to the tendency of the argument, I must not admit the statement. Man is superior in organization to the brutes, —superior in strength—in that constitutional property which enables him to fulfil his destinies by extending his race in every climate, and living on every variety of nutriment. Gather together the most powerful brutes, from the arctic circle or torrid zone, to some central point—they will die, diseases will be generated, and will destroy them. With respect to the superiority of man being in his mind, and not merely in the provisions of his body, it is no doubt true;—but as we proceed, we shall find how the Hand supplies all instruments, and by its correspondence with the intellect gives him universal dominion. It presents the last and best proof of that principle of adaptation, which evinces design in the creation.

Another notion which we meet with, is, that the variety of animals is not a proof of design, as showing a relation between the formation of their organs, and the necessity for their exercise: but that the circumstances in which the animal has been placed, have been the cause of the variety. The influence of these circumstances, it is pretended, has, in the long progress of time, produced a complication of structure out of an animal which was at first simple. We shall reserve the discussion of this subject until we have the data before us; which of themselves, and without much argument, will suffice to overthrow it. I may notice here another idea of naturalists, who are pleased to reduce these changes in the structure of animals into general laws. They affirm that in the centre of the animal body there is no disposition to change, whilst in the extremities we see surprising variations of form. If this be a law, there is no more to be said about it, the inquiry is terminated. But I contend that the term is quite inapplicable, and worse than useless, as tending to check inquiry. What then is the meaning of this variation in the extremities and comparative permanence towards the centre of the skeleton? I conceive the rationale to be this, that the central part, by which in fact they mean the skull, spine, and ribs,

are permanent in their offices; whilst the extremities vary and are adapted to every exterior circumstance. The office of the back part of the skull is to protect the brain, that of the spine to contain the spinal marrow, and the ribs to perform respiration. Why should we expect these parts to vary in shape while their office remains the same? But the shoulder must vary in form, as it does in motion. The shape of the bones and the joints of the extremities must be adapted to their various actions, and the carpus and phalanges must change, more than all the rest, to accommodate the extremity to its different offices. Is it not more pleasing to see the reason of this most surprising adjustment, than merely to say it is a law?

There is yet another opinion, which will suggest itself by the perusal of the following chapter, to those who have read the more modern works on Natural History. It is supposed that the same elementary parts belong to all animals, and that the varieties of structure are attributable to the transposition and moulding of these elementary parts. I find it utterly impossible to follow up this system to the extent which its abettors would persuade us to be practicable. I object to it as a means of engaging us in very trifling pursuits,—and of diverting the mind from the truth; from that conclusion, indeed, to which I may avow it to be my intention to carry the reader. But this discussion also must follow the examples, and we shall resume it in a latter part of the volume.

CHAPTER III.

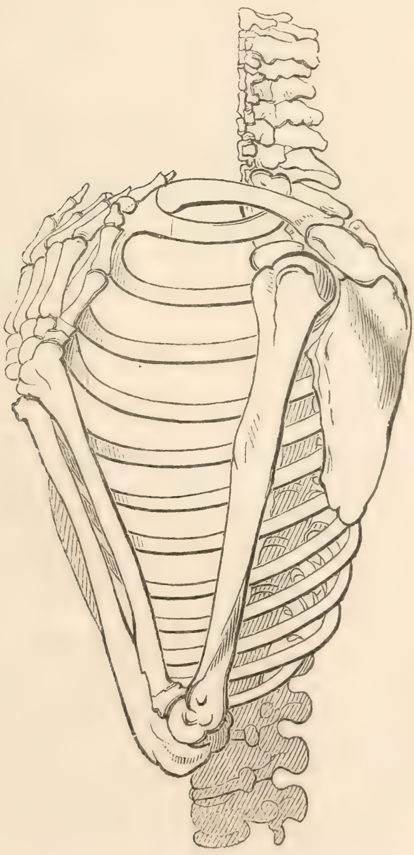
THE COMPARATIVE ANATOMY OF THE HAND.

In this inquiry, we have before us what in the strictest sense of the word is a system. All the individuals of the extensive division of the animal kingdom which we have to review, possess a cranium for the protection of the brain,—a heart, implying a peculiar circulation,—five distinguishable organs of sense; but the grand peculiarity, whence the term vertebrata is derived, is to be found in the spine; that chain of bones which connects the head and body, and, like a keel, serves as a foundation for the ribs; or as the basis of that fabric which is for respiration.

I have said, that we are to confine ourselves to a portion only of this combined structure; to separate and examine the anterior extremity, and to observe the adaptation of its parts, through the whole range of these animals. We shall view it as it exists in man, and in the higher division of animals which give suck, the mammalia—in those which propagate by eggs, the oviparous animals,—

birds, reptiles, amphibia, and fishes; and we shall find the bones which are identified by distinct features, adjusted to various purposes, in all the series, from the arm to the fin. We shall recognise them in the mole, formed into a powerful apparatus for digging, by which the animal soon covers itself, and burrows its way under ground. In the wing of the eagle we shall count every bone adapted to a new element, and as powerful to rise in the air, as the fin of the salmon is to strike through the water. The solid hoof of the horse, the cleft foot of the ruminant, the retractile claw of the feline tribe, the long folding nails of the sloth, are among the many changes that are found in the adjustment of the chain of bones which, in man, ministers to the compound motions of the hand.

OF THE SHOULDER.



Were it my purpose to teach the elements of this subject, I should commence with examining the lowest animals, and trace the bones of the anterior extremity as they come to resemble the human arm, and to be employed for a greater variety of uses in the higher animals; but as my present object is illustration only, I shall begin with the human hand, and compare its parts. With this view, I shall divide the extremity into the shoulder, arm, and hand, and treat each subdivision with a reference to its structure in animals.

In viewing the human figure, or human skeleton, in connexion with our present subject, we remark the strength and solidity of the lower extremities, in contrast with the superior. Not only are the lower limbs longer and larger than those of any other animal, but the pelvis is wider, and the obliquity of the neck of the thigh-bone greater. The distances of the larger processes on the upper ends of the thigh-bones (the trochanters,) from the sockets are also greater than in any of the vertebrata. Altogether the strength of these bones, the size and prominence of their processes, the great mass of the muscles of the loins and hips, distinguish man from every other animal; they secure to him the upright posture, and give him the perfect freedom of the arms, for purposes of ingenuity and art.

The Chimpanzee* is an ape which stands high in the order of quadrumana, yet we cannot mistake his capacities: that the lower extremities and pelvis, or hips, were never intended to give him the erect posture, or only for a moment; but, for swinging, or for a vigorous pull, who can deny him power in those long and sinewy arms.

The full prominent shoulders, and the consequent squareness of the trunk, are equally distinctive of man, with the strength of his loins; they indicate a free motion of the hand.

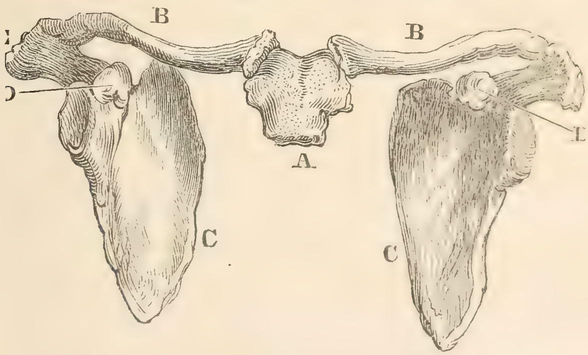
OF THE BONES OF THE SHOULDER.

The bones of the shoulder, being those which give firm attachment to the upper extremity, and which afford origins to the muscles of the arm and fore arm, are simple, if studied in man, or, indeed, in any one genus of animals; but considered in reference

* *Simia troglodytes*, from the coast of Guinea, more human in its form, and more easily domesticated than the ourang-outang. We would do well to consider the abode of these creatures in a state of nature—vast forests extending in impenetrable shade below, whilst above, and exposed to the light, there is a scene of verdure and beauty; this is the home of those monkeys and lemurs which have extremities like hands. In many of them the hinder extremity has the more perfect resemblance to a hand; in the Goaita we see the great toe assuming the characters of a thumb, whilst in the fore paw, the thumb is not distinguishable, being hid in the skin. In short, these paws are not approximations to the hand, corresponding with a higher ingenuity, but are adaptations of the feet to the branches on which the animals climb.

to the whole of the vertebral animals, they assume a very extraordinary degree of intricacy. We shall, however, find that they retain their proper office, notwithstanding the strange variations in the form of the neighbouring parts. In man they are directly connected with the great apparatus of respiration; but in other animals we shall see the ribs, as it were, withdrawn from them, and the bones of the shoulder, or fundamental bones of the extremity, curiously and mechanically adapted to perform their office, without the support of the thorax. We shall not, however, anticipate the difficulties of this subject, but look first upon that which is most familiar and easy, the shoulder of man in comparison with the varieties in the mammalia.

The *clavicle*, or collar bone, is that which runs across from the breast bone to the top of the shoulder. The square form of the chest, and the free exercise of the hand, are very much owing to this bone. It keeps the shoulders apart from the chest, and throws the action of the muscles upon the arm bone, which, but for it, would be drawn inwards, and contract the upper part of the trunk.



If we take the motions of the anterior extremity in different animals, as our guide, we shall see why this bone is perfect in some, and entirely wanting in others. Animals which fly, or dig, or climb, as bats, moles, porcupines, squirrels, ant-eaters, armadilloes, and sloths, have this bone, for in them, a lateral or outward motion is required. There is also a certain degree of freedom in the anterior extremity of the cat, dog, martin, and bear; they strike with the paw, and rotate the wrist more or less extensively, and they have therefore a clavicle, though an imperfect one. In some of these, even in the lion, the bone which has the place of the clavicle is very imperfect indeed; and if attached to the shoulder, it does not extend to the sternum; it is concealed in the flesh, and is like

A. Triangular portion of the Sternum. B. B. Clavicles. C. C. Scapulæ. D. Coracoid process of the Scapula. E. Acromion process of the Scapulæ.

the mere rudiments of the bone. But, however imperfect, it marks a correspondence in the bones of the shoulder to those of the arm and paw, and the extent of motion enjoyed.

When the bear stands up, we perceive, by his ungainly attitude and the motion of his paws, that there must be a wide difference in the bones of his upper extremity, from those of the ruminant or solipede. He can take the keeper's hat from his head, and hold it; he can hug an animal to death. The ant-bear especially, as he is deficient in teeth, possesses extraordinary powers of hugging with his great paws; and, although harmless in disposition, he can squeeze his enemy, the jaguar, to death. These actions, and the power of climbing, result from the structure of the shoulder, or from possessing a collar bone, however imperfect.

Although the clavicle is perfect in man, thereby corresponding with the extent and freedom of the motion of his hand, it is strongest and longest, comparatively, in the animals which dig or fly, as in the mole and the bat.

Preposterous as the forms of the kangaroo appear to us, yet even in this animal we see a relation preserved between the extremities. He sits upon his strong hind legs and tail, tripod like, with perfect security, and his fore paws are free. He has a clavicle, and possessing that bone and the corresponding motions, is not without means of defence; for with the anterior extremities he seizes the most powerful dog, and then drawing up his hinder feet, he digs his sharp pointed hoofs into his enemy, and striking out, tears him to pieces. Though possessed of no great speed, and without horns, teeth, or claws, and, as we should suppose, totally defenceless, nature has not been negligent of his protection.*

* There is in the form of the kangaroo, and especially in its skeleton, something incongruous, and in contrast with the usual shape of quadrupeds. The head, trunk, and fore paws, appear to be a portion of an animal, unnaturally joined to another of greater dimensions and strength. It is not easy to say what are, or what were, the exterior relations corresponding with the very peculiar form of this animal; but the interior anatomy is accommodated, in a most remarkable manner, to the enormous hinder extremities.

The uterine system of the female is diminutive, and does not undergo the developement, which universally takes place in other animals. The young, instead of remaining within the mother for the period of gestation, become, by some extraordinary mode of expulsion, attached to the teats; where they hang by the mouth, covered by an exterior pouch, until, from minute and shapeless things, they are matured to the degree in which the young of other animals are usually produced. The artery which supplies the milk glands, is the epigastric, a branch of the great artery of the thigh; and in this curious manner is the provision for the young drawn from the great limbs of the mother,—certainly the part best enabled to supply it.

I think I perceive the reason of this very peculiar manner of bringing forth the young, to be in the form of the animal and its upright position. The argument would stand thus, were we here at liberty to discuss it: 1. An upright position of the mother requires a pelvis of a peculiar and complex construction. 2. A pelvis, of this construction, requires that the form of the offspring shall accurately correspond, and that the anterior part of the fœtus shall much exceed in size the posterior parts.

It cannot be better shown, that the function or use of a part, determines its form, than by looking to the clavicle and scapula of the bird.

Three bones converge here, to the shoulder joint, the furculum, clavicle, and scapula; but none of these have the resemblance which their names would imply. The scapula is the long thin bone, like the blade of a knife; and the clavicle is that stronger portion of bone which is articulated with the breast bone: this leaves the furculum as a new part. Now I think, that the furculum, or fork bone, which in carving, we detach, after removing the wings of a fowl, corresponds with the form and place of the clavicle; and if we so consider it, we may then take the strong bone, commonly called the clavicle, as a process of the irregularly formed scapula. However this may be, what we have to admire in birds, is the mode in which the bones are fashioned, to strengthen the articulation of the shoulder, and to give extent of surface for the attachment of muscles.

Another peculiarity in birds is, that there is not an alternate motion of the wings; their extremities, as we may continue to call them, move together in flying; and, therefore, the clavicles are joined, forming the furculum.

OF THE SCAPULA.

If we attend to the scapula, or shoulder-blade, we shall better understand the influence of the bones of the shoulder, on the motions and speed of animals. The scapula is that flat triangular bone, which, lying on the ribs, and cushioned with muscles, shifts and revolves with each movement of the arm. The muscles converge from all sides towards it, from the head, spine, ribs, and breast bone. These acting in succession, roll the scapula and toss the arm, in every direction. When the muscles combine in action, they fix the bone, and either raise the ribs in drawing breath, or give firmness to the whole frame of the trunk.

Before I remark further on the influence of the scapulæ on the motions of the arm, I shall give an instance in proof of a very important function which they perform. Hearing that there was a lad of fourteen years of age, born without arms, I sent for him. I found that indeed he had no arms, but he had clavicles and

3. But the kangaroo is, in shape, the very reverse,—the head could not, consistently with the conformation of the whole animal, be larger than the hips and hinder extremities. 4. Nature has accomplished her work safely, and by the simplest means, by anticipating the period of the separation of the fœtus, and providing for the growth of the offspring, exterior to the circle of bones through which its birth must take place. It will, perhaps be objected to this reasoning, that the order *didelphis* (with a double womb) embraces animals which have no such remarkable disproportion in the hinder extremities.

scapulæ. When I made this boy draw his breath, the shoulders were raised, that is to say, the scapulæ were drawn up, were fixed, and became the points from which the broad muscles of the chest diverged towards the ribs, to draw and expand them in respiration. We would do well to remember this double office of the scapula and its muscles, that whilst it is the very foundation of the bones of the upper extremity, and never wanting in any animal that has the most remote resemblance to an arm, it is the centre and point d'appui of the muscles of respiration, and acts in that capacity, where there are no extremities at all!

We perceive, that it is only in certain classes of animals, that the scapula is joined to the trunk by bone, that is, through the medium of a clavicle; and a slight depression on a process of the scapula, when discovered in a fossil state, will declare to the geologist, the class to which the animal belonged. For example, there are brought over to this country the bones of the Megatherium, an animal, which must have been as large as the elephant; of the anterior extremity there is only the scapula; and on the extremity of the process, which is called acromion, of that bone, there is a mark of the attachment of a clavicle. This points out the whole constitution of the extremity, and that it enjoyed perfect freedom of motion. Other circumstances will declare whether that extensive motion was bestowed, so that the animal might dig with its huge claws like some of the edentata, or strike like the feline tribe.

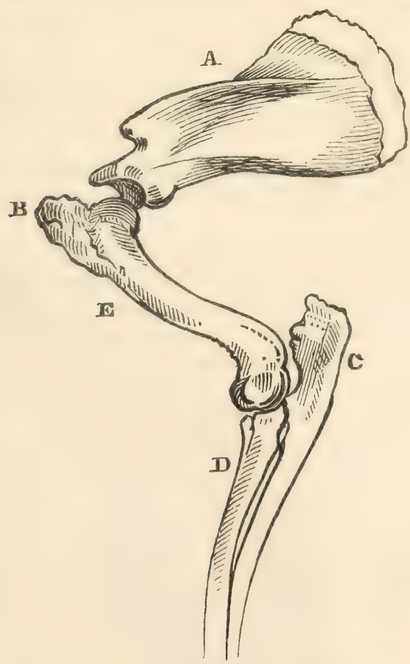
Some interest is attached to the position of the scapula, in the horse. In him, and in other quadrupeds, with the exceptions which I have made, there is no clavicle, and the connexion between the extremity and the trunk, is solely through muscles. That muscle, called serratus magnus, which is a large one in man, is particularly powerful in the horse; for the weight of the trunk hangs upon this muscle. In the horse, as in most quadrupeds, the speed results from the strength of the loins and hinder extremities, for it is the muscles there which propel the animal. But were the anterior extremities joined to the trunk firmly, and by bone, they could not withstand the shock from the descent of the whole weight thrown forwards; even though they were as powerful as the posterior extremities, they would suffer fracture or dislocation. We cannot but admire, therefore, the provision in all quadrupeds whose speed is great, and whose spring is extensive, that, from the structure of their bones, they have an elastic resistance, by which the shock of descending is diminished.

If we observe the bones of the anterior extremity of the horse, we shall see that the scapula is oblique to the chest; the humerus, oblique to the scapula; and the bones of the fore-arm at an angle with the humerus. Were these bones connected together in a straight line, end to end, the shock of alighting would be conveyed through a solid column, and the bones of the foot, or the joints, would suffer from the concussion. When the rider is thrown

forwards on his hands, and more certainly when he is pitched on his shoulder, the collar bone is broken, because in man, this bone forms a link of connexion between the shoulder and the trunk, so as to receive the whole shock; and the same would happen in the horse, the stag, and all quadrupeds of great strength and swiftness were not the scapulæ sustained by muscles, and not by bone, and did not the bones recoil and fold up.

The horse-jockey runs his hand down the horse's neck, in a knowing way, and says, "this horse has got a heavy shoulder, he is a slow horse!" He is right, but he does not understand the matter; it is not possible that the shoulder can be too much loaded with muscle, for muscle is the source of motion, and bestows power. What the jockey feels, and forms his judgment on, is the abrupt transition from the neck to the shoulder, which, in a horse for the turf, ought to be a smooth undulating surface. This abruptness, or prominence of the shoulder, is a consequence of the upright position of the scapula; the sloping and light shoulder results from its obliquity. An upright shoulder is the mark of a stumbling horse: it does not revolve easily, to throw forward the foot.

Much of the strength, if not the freedom and rapidity of motion, of a limb, will depend on the angle at which the bones lie to each



A. Scapula. E. Humerus. B. Tuberosity of the Humerus. C. Olecranon or projection of the Ulna. D. Radius.

other; for, this mainly affects the insertion, and, consequently, the power of the muscles. We know, and may every moment feel, that when the arm is extended, we possess little power in bending it; but as we bend it the power is increased; which is owing to the change in the direction of the force acting upon the bone; or, in other words, because the tendon becomes more perpendicular to the lever. A scapula which inclines obliquely backwards, increases the angle at which it lies with the humerus, and, consequently, improves the effect of those muscles which pass from it to the humerus. We have only to turn to the skeleton of the elephant, the ox, the elk, or the stag, to see the confirmation of this principle. When the scapula is oblique, the serratus muscle, which passes from the ribs to its uppermost part, has more power in rolling it. When it lies at right angles with the humerus, the muscles which are attached to the latter, (at B.) act with more effect. And on the same principle, by the oblique position of the humerus, and, consequently, its obliquity in reference to the radius and ulna, the power of the muscle inserted (at C.) into the olecranon, is increased. On the whole, both power and elasticity are gained by this position of the superior bones of the fore-leg. It gives to the animal that springs, a larger stretch in throwing himself forwards, and security, in a soft descent of his weight. A man, standing upright, cannot leap or start off at once; he must first sink down, and bring the bones of his extremities to an angle. But the antelope, or other timid animals of the class, can leap at once, or start off in their course without preparation: another advantage of the oblique position of their bones when at rest.

The leg of the elephant is obviously built for the purpose of sustaining the huge bulk of the animal, whilst in the camel we have a perfect contrast.

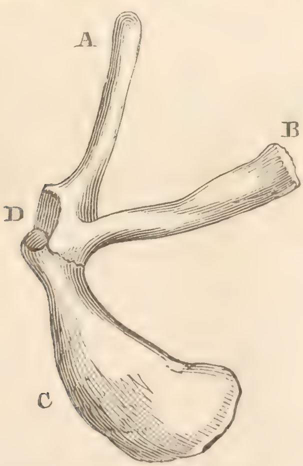
Were we to compare the bones of these larger animals with any form of architecture, we might say, it was the Egyptian, or rather like the Cyclopean walls of some ancient city; they are huge and shapeless, and piled over each other, as if they were destined more to sustain the weight, than to permit motion.

We further perceive, from the comparison of these sketches, that if the humerus be placed obliquely, it must necessarily be short, otherwise it would throw the leg too far back, and make the head and neck project. It is one of the "points" of a horse to have the humerus short. And not only have all animals of speed this character, but birds of long flight, as the swallow, have short humeri. This is owing, I think, to another circumstance, that in the wing, the short humerus causes a quicker extension; for the further extremity of the bone moving in a lesser circle, makes the gyration be more rapid.

If we take the bones of the shoulder as a distinct subject, and trace them comparatively, we shall be led to notice some very curious modifications in them. We have already seen that there are

two objects to be attained in the construction of these bones. In man, and mammalia, they constitute an important part of the organ of respiration; and they conform to the structure of the thorax. But we shall find that in some animals, this function is in a manner withdrawn from them; the scapulæ and the clavicles are left without the support of the ribs.—These bones forming the shoulder, therefore, require additional carpentry; or they must be laid together on a new principle. In the batrachian order, for example in the frog, the thorax, as constituted of ribs, has disappeared; the mechanism of respiration is altogether different from what it is in the mammalia. Accordingly, we find that the bones of the shoulder are on a new model; they form a broad and flat circle, sufficient to give secure attachment to the extremity, and affording a large space for the lodgment of the muscles which move the arm.—Perhaps the best example of this structure is in the siren and proteus; where the ribs are reduced to a few imperfect processes, attached to the anterior dorsal vertebræ; and where the bones of the extremity, being deprived of all support from the thorax, depend upon themselves for security. Here the bones, corresponding to the sternum, clavicles, and scapulæ, are found clinging to the spine, and forming, like the pelvis, a circle, to the lateral part of which the humerus is articulated.

In the chelonian order, the tortoises, we see another design accomplished, in the union of these bones; and the change is owing to a very curious circumstance. The spine and ribs of these animals form the rafters of their strong shell; and consequently they are external to the bones of the shoulder. The scapulæ and clavicles being thus within the thorax, and having nothing in their grasp, neither ribs nor spine, they must necessarily fall together, and form



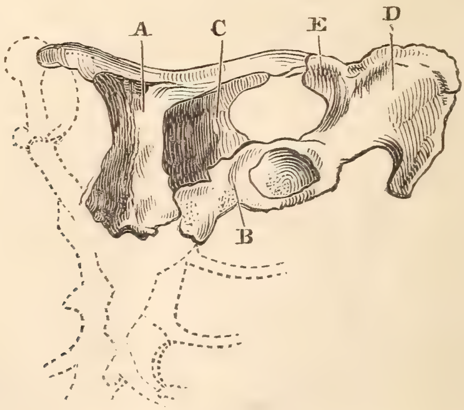
A. Scapula. B. Acromion process. C. Coracoid bone. D. Glenoid cavity.

a circle, in order to afford a fixed point to which the extremity may be attached. It would, indeed, be strange if, now being joined for the purpose of giving attachment to the humerus, and in circumstances, as we may express it, so very new, they preserved any resemblance to the forms which we have been contemplating in the higher animals. In the figure on the preceding page, we have the bones of the shoulder of the turtle; and it is readily perceived how much they have changed both their shape and their offices. That part which is most like a scapula in shape, lies on the fore part, instead of the back part; and the bones which hold the shoulders apart, abut upon the spine, instead of upon the sternum. Hence it appears idle to follow out these bones under the old denominations, or such as are applicable to their condition in the higher animals.

In fishes, where the apparatus of respiration has undergone another entire change, and where there are no proper ribs, the bones which give attachment to the pectoral fin, are still called the bones of the shoulder; and that which is named scapular appendage, is, in fact, attached to the bones of the head. So that the whole consists of a circle of bones, which, we may say, seek security of attachment by approaching the more solid part of the head, in defect of a firm foundation in the thorax.

Thus, the bones which, in a manner, give a foundation to those of the anterior extremity, have been submitted to a new modelling, in correspondence with every variety in the apparatus of respiration; and they have yet maintained their pristine office.

The naturalist will not be surprised, on finding an extraordinary intricacy in the shoulder apparatus of the ornithorynchus paradoxus, since the whole frame and organs of this animal imply, that it is intermediate between mammalia and birds; and it is placed in the



A. Clavicle. B. Coracoid bone. C. A new bone, introduced into the apparatus, which articulates with the coracoid bone, and lies interior to the clavicle. D. Scapula. E. Acromion Scapulæ.

list of edentata. We introduce it here, as another instance of the changes which the bones of the shoulder undergo with every new office, and in correspondence with the motions, of the extremity: whether it be to support the weight in running, or to give freedom to the arm, or to provide for flying, or for performing equally the act of creeping and of swimming.

Unprofitable as the inquiry may seem, there is no other way by which the geologist can distinguish the genera of those oviparous reptiles, which he finds imbedded in the secondary strata, than by studying the minute processes and varying characters of these bones, in the different classes of animals. In the ichthyosaurus, and plesiosaurus, the inhabitants of a former world, and now extinct, we perceive a considerable deviation from the perfection of the bones of the arm and hand, compared with the frog and tortoise: but if strength is the object, there is a greater degree of perfection in the bones of the shoulder. The explanation of this is, that the ribs and sterno-costal arches, constituting the thorax are more perfect, than in the chelonian and batrachian orders; and the bones of the shoulder are therefore external, and resemble those of the crocodile; yet the ribs are so weak as to be incapable of sustaining the powerful action of the anterior extremities; accordingly, the bones, which by a kind of license we continue to call clavicle, omoplate or scapula, and coracoid, though strangely deviating from the original form and connections, constitute a texture of considerable strength, which perfects the anterior part of the trunk, and gives attachment and lodgment to the powerful muscles of the paddle.

But in giving their attention to this subject, it does not appear that naturalists have hit upon the right explanation of the peculiar structure, and curious varieties of these bones. Why is the apparatus of respiration so totally changed in these classes of animals?

They are cold-blooded animals; they require to respire less frequently than other creatures, and they remain long under water. I conceive that the peculiarity in their mode of respiration corresponds with this property. Hence their vesicular lungs, their mode of swallowing the air, instead of inhaling it; and hence, especially, their power of compressing the body and expelling the air; it is this, I imagine, which enables them to go under the water and crawl upon the bottom; without this, that is to say, had they possessed the lungs of warm-blooded animals, which are compressible only in a slight degree, their capacity of remaining under water would have left them struggling against their buoyancy, like a man or any of the mammalia when diving. The girdle of bones of the shoulder is constituted with a certain regard to the peculiar action of respiration, and to the pliancy of the body, in order that the vesicular lungs may be compressed, and the specific weight diminished. The facility which the absence of ribs gives, in the batrachian order, and the extreme weakness and pliancy of these

bones in the saurians, for admitting the compression of the lungs extended through the abdomen, must be, as I apprehend, peculiarities adapted to the same end.

OF THE HUMERUS.

The demonstration of this bone need not be so dry a matter of detail as the anatomist makes it. We may see in it that curious relation of parts which has been so successfully employed by Paley to prove design, and from which the genius of Baron Cuvier has brought out some of the finest examples of inductive reasoning.

In looking to the head of this bone in the human skeleton, (see the fig. page 31,) we observe the great hemispherical surface for articulation with the glenoid cavity of the scapula, and we see that the two tubercles, near the joint, are depressed, and do not interfere with the revolving of the humerus, by striking against the scapula.

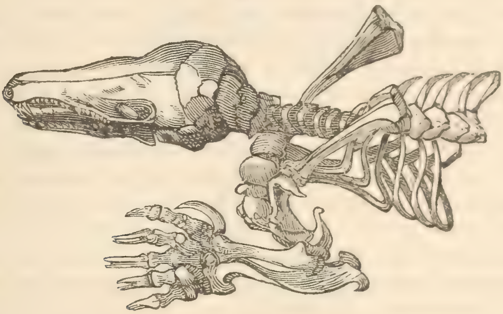
Such appearances alone are sufficient to show that all the motions of the arm are free. To give assurance of this, suppose that the geologist has picked up this bone in interesting circumstances. To what animal does it belong? The circular form of the articulating surface, and the very slight projection of the tubercles, evince a latitude and extent of motion. Now, freedom of motion in the shoulder, implies freedom also in the extremity or paw, and rotation of the bones of the wrist. Accordingly, we direct the eye to that part of this humerus which gives origin to the muscles for turning the wrist, (the *Supinator muscles*), and in the prominence and length of the ridge or crest which is on the lower and outer side of the bone, we have proofs of the free motion of the paw.

Therefore, on finding the humerus thus characterised, we conclude, that it belonged to an animal with sharp moveable claws; that, in all probability, it is the remains of a bear.

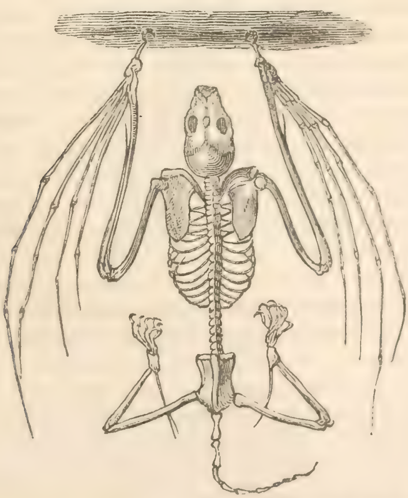
But, suppose that the bone found has a different character:—That the tubercles project, so as to limit the motion to one direction, and that the articulating surface is less regularly convex. On inspecting the lower extremity of such a bone, we shall perceive provisions for a deeper and more secure hinge-joint at the elbow; and neither in the form of the articulating surface, (which is here called trochlea), nor in the spine on the outside, above noticed, will there be signs of the rotation of the fore-arm on the other. We have, therefore, got the bone of an herbivorous quadruped, either with a solid or with a cloven foot.

In the bat and mole we have, perhaps, the best examples of the moulding of the bones of the extremity, to correspond with the condition of the animal. The mole is an animal fitted to plough its way under ground. In the bat, the same system of bones is adapted to form a wing, to raise the animal in the atmosphere; and with a provision to cling to the wall, not to bear upon. We recognize in

both, every bone of the upper extremity, but how very differently formed and joined! In the mole, the sternum or breast bone, and the clavicle are remarkably large: the scapula assumes the form of a high lever: the humerus is thick and short, and has such spines for the attachment of muscles, as indicate great power. The spines, which give origin to the muscles of rotation, project in an extraordinary manner; and the hand is large, flat, and so turned, that it may shove the earth aside like a ploughshare.*



There can be no greater contrast to these bones than is presented in the skeleton of the bat. In that animal the bones are light and



* The snout may vary in its internal structure with new offices. Naturalists say that there is a new "element" in the pig's nose. It has, in fact, two bones which admit of motion, whilst they give more strength. Moles have those bones also, as they plough the earth with their snouts. We have noticed the manner in which they use their strong hands; we should add that their head is a wedge, to

delicate; and whilst they are all marvellously extended, the phalanges of the fingers are elongated, so as hardly to be recognized, obviously for the purpose of sustaining a membranous web, and to form a wing.

Contemplating this extraordinary application of the bones of the extremity, and comparing them with those in the wing of a bird, we might say, that this is an awkward attempt—a failure. But before giving expression to such an opinion, we must understand the objects required in this construction. It is not a wing intended merely for flight, but one which, while it raises the animal, is capable of receiving a new sensation, or sensations in that exquisite degree, so as almost to constitute a new sense. On the fine web of the bat's wing, nerves are distributed, which enable it to avoid objects in its flight, during the obscurity of night, when both eyes and ears fail. Could the wing of a bird, covered with feathers, do this? Here then we have another example of the necessity of taking every circumstance into consideration before we presume to criticise the ways of nature. It is a lesson of humility.*

In the next page we have a sketch of the arm-bones of the Anteater,† to show once more the correspondence in the whole extremity. We observe these extraordinary spines of the humerus marking the power of the muscles which are attached to it; for as I have said before, whether we examine the human body, or the comparative forms of the bones, the distinctness of the spines and processes declares the strength of the muscles. It is particularly pleasing to notice here the correspondence between the humerus and the other bones, the scapula large and with a double spine, and with great processes: the ulna projecting at the olecranon, and the radius freely rotating: but above all, in the developement of one grand metacarpal bone, which gives attachment to a strong claw, we see a very distinct provision for scratching and turning aside the ant-hill. The whole is an example of the relation of the particular parts of the skeleton to one another; and were it our business, it would be easy to show, that as there is a correspondence among the bones of the arm, so is there a more universal relation between those of the whole skeleton. As the structure of the bones declares the provision of the extremity for digging into the ant-hills, so we

which their hands are assisting, in throwing aside the earth. The conformation of the head in shape and strength of bones, and the new adjustment of a muscle, which is cutaneous in other animals (the *Platisma Myoides*) to the motions of the head, are among the most curious changes of common parts to new offices.

* Besides the adaptation of the bat for flight, through a new adjustment of the bones of the arm, this animal has cells under its skin; but I know not how far I am authorized to say that they are analogous to the air-cells of birds, or that they are for the purpose of making the bat specifically lighter, They extend over the breast, and under the axillæ in some bats; and they are filled by an orifice which communicates with the pharynx.

† Tamandua, from South America.

shall not be disappointed in our expectation of finding a projecting muzzle unarmed with teeth, and a long tongue provided with a glutinous secretion, to lick up the emmets which are disturbed by the animal's scratching.

In the skeleton of the cape-mole, we may see, from the projecting acromion scapulæ, and a remarkable process of the humerus, that there is a provision for the rotation of the arm, which implies burrowing. But the apparatus seems by no means so perfect as in the mole, implying that it digs in a softer soil than that animal, whilst the possession of gnawing teeth indicates that it lives on roots.

In Birds there is altogether a new condition of parts, as there is a new element to contend with. The very peculiar form and structure of their skeleton may be thus accounted for. First, it is necessary that birds, as they are buoyed in the air, be specifically lighter. Secondly, the circumference of their thorax must be extended, and the motions of their ribs limited, that the muscles of the

wings may have sufficient space and firmness for their attachment. Both these objects are attained by a modification of the apparatus of breathing. The lungs are highly vascular and spongy, but they are not distended with air. The air is drawn through their substance into the large cavity common to the chest and abdomen; and whilst the great office of decarbonization of the blood is securely performed, advantage is taken to let the air into all the cavities, even into those of the bones. From what was said in the introductory chapter, of the weight of the body being a necessary concomitant of muscular strength, we see why birds, by reason of their lightness, as well as by the conformation of their skeleton, walk badly. And, on the other hand, in observing how this lightness is adapted for flight, it is remarkable how small an addition to their body will prevent them rising on the wing. If the griffon-vulture be frightened after his repast, he must disgorge, before he flies; and the condor, in the same circumstances, is taken by the Indians, like a quadruped, by throwing the lasso over it.*

As every one must have observed, the breast-bone of birds extends the whole length of the body; and owing to this extension, a lesser degree of motion suffices to respiration. So that a greater surface, necessary for the lodgement and attachment of the muscles of the wings, is obtained, whilst that surface is less disturbed by the action of breathing, and is more steady. Another peculiarity of the skeleton of the bird is the consolidation of the vertebræ of the back; a proof, if any were now necessary, that the whole system of bones conforms to that of the extremities, the firmer texture of the bones of the trunk, being a part of the provision for the attachment of the muscles of the wings.†

The vertebræ of the back being fixed in birds, and the pelvis reaching high, there is no motion in the body; indeed, if there were, it would be interrupted by the sternum. We cannot but admire, therefore, the composition of the neck and head, and how the extension of the vertebræ, and the length and pliability of the neck, whilst they give to the bill the office of a hand, become a substitution for the loss of motion in the body, by balancing the whole, as in standing, running, or flying. Is it not curious to observe how the whole skeleton is adapted to this one object, the power of the wings?

Whilst the ostrich has no keel in its breast-bone, birds of passage are, on dissection, recognisable by the depth of this ridge of the sternum. The reason is that the angle, formed by this process and

* It is interesting to notice the relations of great functions in the animal economy. Birds are oviparous, because they never could have risen on the wing had they been viviparous; if the full stomach of a carnivorous bird retard its flight, we perceive that it could not have carried its young. The light body, the quill-feathers, the bill, and the laying of eggs, are all necessarily connected.

† The ostrich and cassowary, which are rather runners than fliers, have the spine loose.

the body of the bone, affords lodgement for the pectoral muscle, the powerful muscle of the wing. In this sketch of the dissection of the swallow, there is a curious resemblance to the human arm, and we cannot fail to observe, that the pectoral muscle constitutes the greater part of the bulk of the body.* And here we see the correspondence between the strength of this muscle and the rate of flying of the swallow, which is a mile in a minute, for ten hours every day, or six hundred miles a day.† If it be true that birds, when migrating, require a wind that blows against them, it implies an extraordinary power, as well as continuance of muscular exertion.

We see how Nature completes her work, when the intention is that the animal shall rise buoyant and powerful in the air:—the whole texture of the frame is altered and made light, in a manner consistent with strength. We see also how the mechanism of the anterior extremity is changed, and the muscles of the trunk differently directed. But we are tempted to examine those means, which we would almost say are more awkwardly suited for their purpose, where the system of bones and muscles, peculiar to the quadruped, is preserved, while a power of launching into the air is also given. We have already noticed the structure of the bat as adapted to flight; but there are other animals which enjoy this function in a lesser degree. For example, the flying squirrel (Petromys Volucella,) being chased to the end of the bough, spreads out its mantle from one extremity to the other, and drops in the air; but with such a resistance from its extended skin and its tail, that it can direct its flight obliquely downwards, and even turn in the air. But to this end, there is no necessity for any adaptation of the anterior extremity. Among reptiles there is a provision of the same kind, in the Draco fimbriatus; which is capable of creeping to a height, and dropping safely to the ground, under the protection of a sort of parachute, formed by its extended skin. This is not an inapt illustration, for although the phalanges of the fingers are not here used to extend the web, the ribs, which are unnecessary for breathing, are prolonged like the whalebone of an umbrella, and on them the skin is expanded.

But this brings us to a very curious subject,—the condition of those Saurian reptiles, the remains of which are found only in a fossil state, in what are termed the ancient strata of the Jura. The Pterodactyle of Cuvier is an animal which seems to confound all our notions of system. Its mouth was like the long bill of a bird, and its flexible neck corresponded; but it had teeth in its jaws like those of a crocodile. It had the bones of the anterior extremity prolonged,

* Borelli makes the pectoral muscles of a bird, exceed in weight all the other muscles taken together; whilst the pectoral muscles of man, are but a seventieth part of the whole mass of the muscles.

† Mr. White says truly, that the swift lives on the wing; it eats, drinks, and collects materials for its nest in flying, and never rests but during darkness.

and fashioned somewhat like those in the wing of a bird; but it could not have had feathers, as it had not a proper bill. We see no creature having feathers without a bill to dress and prim them. Nor did this extremity resemble the structure in that of a bat: instead of the phalanges being equally prolonged, the second only was extended to an extraordinary length, whilst the third, fourth, and fifth remained with the length and articulation of a quadruped, and with sharp nails, corresponding with the pointed teeth. The extended metacarpal bone reached double the whole length of the animal, and the conjecture is, that upon it was extended a membrane, resembling that of the Draco fimbriatus. In the imperfect specimens which we have, we cannot discover in the height of the pelvis, the strength of the vertebræ of the back, or the expansion of the sternum, a provision for the attachment of muscles commensurate with the extent of the supposed wing. The humerus, and the bones, which we presume are the scapula and coracoid, bear some correspondence to the extent of the wing; but the extraordinary circumstance of all, is the size and strength of the bones of the jaw and vertebræ of the neck, compared with the smallness of the body, and the extreme delicacy of the ribs; which make it, altogether, the thing most incomprehensible in nature.

OF THE RADIUS AND ULNA.

The easy motion of the hand, we might imagine to be in the hand itself; but, on the contrary, the movements which appear to belong to it, are divided among all the bones of the extremity.*

The head of the humerus is rotatory on the scapula, as when making the guards in fencing; but the easier and finer rolling of the wrist is accomplished by the motion of the radius on the ulna.

The ulna has a hooked process, the olecranon, which catches round the lower end of the humerus or arm-bone, (this articulating portion is called trochlea), and forms with it a hinge-joint. The radius, again, has a small, neat, round head, which is bound to the ulna by ligaments, as a spindle is held in the bush. This bone turns on its axis and, as it turns, carries the hand with it, because the hand is strictly attached to its lower head alone. This rolling, is what is termed pronation and supination.

Such a motion would be useless, and a source of weakness in an animal that had a solid hoof. Accordingly, in the horse, these bones are united together and consolidated in the position of pronation.

It is interesting to find that by studying the processes of the bones,

* In the sketch in the next page, the upper bone of the fore-arm is the radius, and in revolving on the lower bone, the ulna, it carries the hand with it.

than which nothing, at first sight, appears more inconsequent, we are learning the characters of a language which shall enable us to read monuments of the highest interest;—the records of the creation, which give an account of the revolutions of the earth itself.

If a geologist should find the nearer head of the radius, and see in the extremity of it a smooth depression, where it bears against the humerus, and observe the polished circle that turns on the cavity of the ulna,—he would say,—This animal had a paw—it had a motion at the wrist, which implies claws. Claws may belong to two species of animals; the feline, which is possessed of sharp carnivorous teeth, or to animals without teeth. If he should find the lower extremity of this same bone, and observe on it spines and grooves for the distinct tendons which disperse to the phalanges, he would conclude that there must have been moveable claws—that it belonged to a carnivorous animal; and he would seek for canine teeth of a corresponding size.

OF THE WRIST AND HAND.

In the human hand, the bones of the wrist (carpus) are eight in number; and they are so closely connected that they form a sort of ball, which moves on the end of the radius. Beyond these, and towards the fingers are the metacarpal bones, which diverge at their further extremities, and give support to the bones of the fingers. The thumb has no metacarpal bone, and is directly articulated with the carpus or wrist. There are thus in the hand twenty-nine bones, from the mechanism of which, result strength, mobility, and elasticity.

Lovers of system (I do not use the term disparagingly) delight to trace the gradual substraction of the bones of the hand. Thus, looking to the hand of man, they see the thumb fully formed—in the simiæ they find it exceedingly small; in one of them, the spider-monkey, it has disappeared, and the four fingers are sufficient, with hardly the rudiments of a thumb. In some of the tardigrade animals, there are only three metacarpal bones with their fingers. In the horse, the cannon bone may be shown to consist of two metacarpal bones. Indeed, we might go further and instance the wing of the bird. To me, this appears to be losing the sense, in the love of system. There is no regular gradation, but a variety, most curiously adapting, as I have often to repeat, the same system of parts to every necessary purpose.

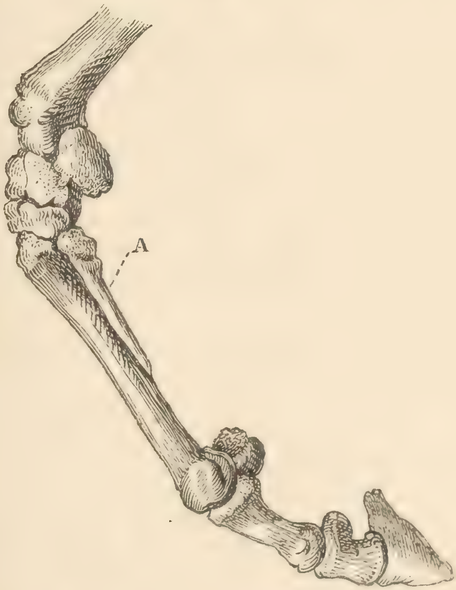
In a comparative view of these bones, we are led more particularly to notice the foot of the horse; it is universally admitted to be of a beautiful design, and calculated for strength and elasticity, and especially provided against concussion.

The bones of the fore-leg of the horse become firmer as we trace them downwards. The two bones corresponding with those of the fore-arm, are braced together and consolidated; and the motion at the elbow joint is limited to flexion and extension. The carpus, forming what by a sort of licence is called the knee, is also new modelled; but the metacarpal bones and phalanges of the toes are totally changed, and can hardly be recognized. When we look in front, instead of the four metacarpal bones, we see one strong bone, the cannon bone, and posterior to this, we find two lesser bones, called splint bones. The heads of these lesser bones enter into the knee-joint; but at their lower ends they diminish gradually, and they are held by an elastic ligamentous attachment to the sides of the cannon bone.

I have some hesitation in admitting the correctness of the opinion of veterinary surgeons of this curious piece of mechanism. They imagine that these moveable splint bones, by playing up and down, as the foot is alternately raised and pressed to the ground, bestow elasticity and prevent concussion.—The fact certainly is, that by over-action this part becomes inflamed, and the extremities are pre-

ternaturally joined by bone to the greater metacarpal or cannon bone; and that this, which is called a splint, is a cause of lameness.

I suspect, rather, that in the perfect state of the joint, these lesser metacarpal bones act as a spring to throw out the foot, when it is raised and the knee-joint bent. If we admit that it is the quickness in the extension of this joint on which the rate of motion must principally depend, it will not escape observation, that in the bent position of the knee, the extensor tendons have very little power, owing



to their running so near the centre of motion in the joint; and that, in fact, they require some additional means to aid the extension of the leg.

Suppose that the head of the lesser metacarpal bone A enters into the composition of the joint, it does not appear that by its yielding, when the foot is upon the ground, the bones of the carpus can descend, as long as they are sustained by the greater metacarpal or cannon bone. I do not, therefore, conceive that this bone can add to the elasticity of the foot. But when we perceive that the head of the splint bone is behind the centre of motion in the joint, it is obvious that it must be more pressed upon, in the bent condition of the joint when the foot is elevated, and that then, the bone must descend. If it be depressed when the foot is raised, and have a power of recoiling (which it certainly has) it must aid in throwing out the leg into the straight position and assist the extensor muscles. Fur-

ther, we can readily believe that when the elasticity of these splint bones is lost, by ossification uniting them firmly to the cannon bone, the want of such a piece of mechanism, essential to the quick extension of the foot, will make the horse apt to come down.

In looking to this sketch, and comparing it with that of the hand on page 49, we see that in the horse's leg the five bones of the first digital phalanx are consolidated into the large pastern bone; those of the second phalanx, into the lesser pastern or coronet; and those of the last phalanx, into the coffin bone.

Of the horse's foot.—But the foot itself deserves our attention. The horse, a native of extensive plains and steppes, is perfect in his structure, as adapted to these, his natural pasture grounds. When brought, however, into subjection, and running on our hard roads, his feet suffer from concussion. The value of the horse, so often impaired by lameness of the foot, has made that part an object of great interest: and I have it from the excellent professor of veterinary surgery to say, that he has never demonstrated the anatomy of the horse's foot without finding something new to admire.

The weight and power of the animal require that he should have a foot in which strength and elasticity are combined. The elasticity is essentially necessary to prevent percussion in striking the ground; and it is attained here, through the united effect of the oblique position of the bones of the leg and foot—the yielding nature of the suspending ligament, and the expansibility of the crust or hoof. So much depends on the position of the pastern bones and coffin bone, that judging by the length of these and their obliquity, it is possible to say whether a horse goes easily, without mounting it. When the hoof is raised, it is smaller in its diameter, and the sole is concave; but when it bears on the ground it expands, the sole descends so as to become flatter; and this expansion of the hoof laterally, is necessary to the play of the whole structure of the foot. Hence it happens that if the shoe be nailed in such a manner as to prevent the hoof expanding, the whole interior contrivance for mobility and elasticity is lost. The foot, in trotting, comes down solid, it consequently suffers percussion; and from the injury, it becomes inflamed and hot. From this inflammation is generated a variety of diseases, which at length destroy all the beautiful provision of the horse's foot for free and elastic motion.

This subject is of such general interest, that I may venture on a little more detail. The elastic or suspending ligament spoken of above, passes down from the back of the cannon bone, along all the bones, to the lowest, the coffin bone; it yields, and allows these bones to bend. Behind the ligament the great tendons run, and the most prolonged of these, that of the perforans muscle, is principally inserted into the coffin bone, having at the same time other attachments. Under the bones and tendon, at the sole of the foot, there is a soft elastic cushion; this cushion rests on the proper horny frog,

that prominence of a triangular shape which is seen in the hollow of the sole. The soft elastic matter being pressed down, shifts a little backwards, so that it expands the heels at the same time that it bears on the frog, and presses out the lateral part of the crust. We perceive that there is a necessity for the bottom of the hoof being hollow or concave—first, to prevent the delicate apparatus of the foot from being bruised, and, secondly, that elasticity may be obtained by its descent. We see that the expansion of the hoof, and the descent of the sole are necessary to the play of the internal apparatus of the foot.

That there is a relation between the internal structure and the covering, whether it be the nail, or crust, or hoof, we can hardly doubt: and an unexpected proof of this offers itself in the horse. There are some very rare instances of a horse having digital extremities. According to Suetonius, there was such an animal in the stables of Cæsar; another was in the possession of Leo X.; and Geoffrey St. Hilaire, in addition to those, says, that he has seen a horse with three toes on the fore-foot, and four on the hind-foot.* These instances of deviation in the natural structure of the bones were accompanied with a corresponding change in the coverings—the toes had nails, not hoofs.

By these examples, it is made to appear still more distinctly that there is a relation between the internal configuration of the toes and their coverings—that when there are five toes complete in their bones, they are provided with perfect nails—when two toes represent the whole, as in the cleft foot of the ruminant, there are appropriate horny coverings—and that when the bones are joined to form the pastern bones and coffin bone, there is a hoof or crust, as in the horse, couagga, zebra, and ass.

In ruminants there is a cannon bone, but the foot is split into two parts, and this must add to its spring or elasticity. I am inclined to think that there is still another intention in this form; it prevents the foot sinking in soft ground, and permits it to be more easily withdrawn. We may observe how much more easily the cow withdraws her foot from the yielding margin of a river, than the horse. The round and concave form of the horse's foot is attended with a vacuum or suction, as it is withdrawn; while the split and conical shaped hoof expands in sinking, and is easily extricated.

In the chamois and other species of the deer there is an additional toe. A sort of lesser cannon bone, with its two pasterns, supports this toe, and is joined by ligament to the larger cannon bone, so that it must have great elasticity. As a division of the flexor tendon runs into it, it must increase the spring when the animal rises from its crouching position. We see, in these sketches, that the lesser meta-

* Such a horse was not long since exhibited in Town and at Newmarket.

carpal bone, which, in the horse, entered into the joint of the "knee," is here brought down to increase the elasticity, or to expand the foot.

The two lateral toes of the hog are short, and do not touch the ground, yet they must serve to sustain the animal when the foot sinks. In the rein-deer these bones are strong and deep, and the toe, by projecting backwards, extends the foot horizontally—thus giving the animal a broader base to stand on, and adapting it to the snows of Lapland, on the principle of the snow-shoe. The systematic naturalist will call these changes in the size, number, and place of the metacarpal bones "gradations;" I see in them only new proofs of the same system of bones being applicable to every circumstance, or condition of animals, and furnishing us with other instances of *adaptation.*

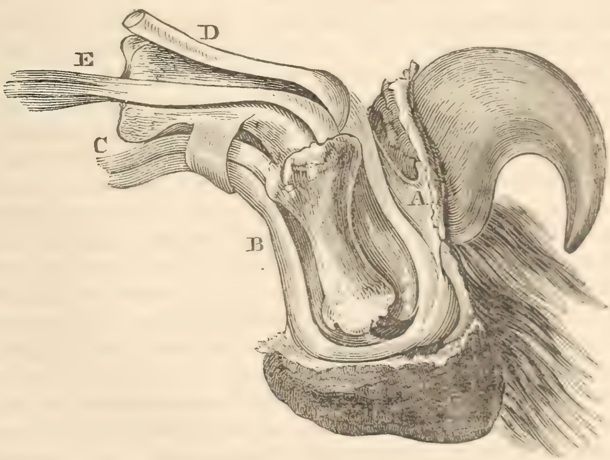
I have explained why I think that the bones of the elephant's leg stand so perpendicularly over each other; there is a peculiarity also in the bones of the foot. In the foot of the living animal we see only a round pliant mass, which, when he stands, resembles the base of a pillar, or the lower part of the trunk of a stately tree. But when we examine the bones of the foot, we find this broad base to consist of the carpus, metacarpus, and phalanges of the toes; and these bones have a very different use from what we have hitherto noticed. They are not connected with a moveable radius, and have no individual motion, as in the carnivorous animal—they merely serve to expand the foot, the base of the column, and to give it a certain elasticity.

In page 39 I have noticed the bones of the foot of the camel in contrast with those of the elephant. The camel's foot having no such disproportioned weight to bear as in the elephant, lightness of motion is secured by the oblique position of its bones, as well as by the direction of the bones of the shoulder, which we have formerly noticed. In the soft texture of the camel's foot there is much to admire; for although the bottom be flat, like the sole of a shoe, yet there is between it and the bones and tendons a cushion, so soft and elastic that the animal treads with great lightness and security. The resemblance of the foot of the ostrich to that of the camel has not escaped naturalists.

We are now treating of the last bones of the toes; and let us see what may be done, by the study of one of these bones, to the bodying forth of the whole animal. I allude to the dissertations of President Jefferson and Baron Cuvier on the Megalonix. But we must preface this part of our subject by some remarks on the form of the claws of the lion.

The canine tribe are carnivorous, like the feline, and both have the last bones of their toes armed with a nail or claw. But their habits and their means of obtaining food are different. The first

combine a keen sense of smelling with a power of continued speed; they run down their prey. The feline order have their superiority in the fineness of their sight, accompanied with a patience, watchfulness, and stealthy movement; they spring upon their prey, and never long pursue it. They attain their object in a few bounds, and, failing, sulkily resume their watch. When we look to the claws, we see a correspondence with those habits. The claws of the dog and wolf are coarse and strong, and bear the pressure and friction incident to a long chase. They are calculated to sustain and protect the foot. But the tiger leaps on his prey, and fastens his sharp and crooked claws in the flesh. These claws being curved and sharp, we must admire the mechanism by which they are preserved. The last bone, that which supports the claw, is placed lateral to the penultimate bone, and is so articulated with it, that an elastic ligament (A) draws it back and raises the sharp extremity of the claw upwards. The nearer extremity of the furthest bone presses the ground in the ordinary running of the animal,* whilst



* The pads in the bottom of the lion's foot cover these bones, or rather, we should say, protect them; they are soft cushions, which add to the elasticity of the foot, and must, in some degree, defend the animal in alighting from its bound. I could not comprehend how the powerful flexor muscles did not unsheath the claws when the lion made its spring, and how they produced this effect when there was an excitement to seize and hold the prey—I made this dissection to detect the cause. The last bone of the toe is placed in a manner so peculiar in relation to the penultimate, being drawn back by the elastic ligament (A) beyond the centre of motion of the joint, that the flexor tendon (B) acting upon it, forces the nearer end, and the cushion of the toe to the ground. But when a more general excitement takes place in the muscles called interossei, and the extensors, D, E, the rela-

the claw is thus retracted into a sheath. But when the tiger makes his spring, the claws are uncased by the action of the flexor tendons; and they are so sharp and strong in the Bengal tiger, and his arm is so powerful, that they have been known to fracture a man's skull by a touch, in the act of leaping over him.

I have alluded to the observation of President Jefferson on the Megalonix. Having found a bone, which by its articulating surface and general form, he recognised to be one of the bones of the phalanx of an animal of great size, he thought he could discover that it had carried a claw; and from this circumstance, he naturally enough concluded (according to the adage—ex ungue leonem) that it must have belonged to a carnivorous animal. He next set about calculating the length of this claw, and estimating the size of the animal. He satisfied himself that in this bone, a relic of the ancient world, he had obtained a proof of the existence, during these old times, of a lion of the height of the largest ox, and an opponent fit to cope with the mastodon. But when this bone came under the scrutiny of Baron Cuvier, his perfect knowledge of anatomy enabled him to draw a different conclusion.

He first observed that there was a spine in the middle of the articulating surface of the last bone, which in this respect was unlike the form of the same bone in the feline tribe. He found no provision in this specimen of an extinct animal, for the lateral attachment of the bone, which we have just noticed to be necessary for its retraction. Then observing what portion of a circle this bone formed, he prolonged the line, and showed that the claw belonging to it must have been of such great length, that it could never have been retracted to the effect of guarding an acute and sharp point. The point, therefore, could not have been raised vertically, so as to have permitted the animal to put the foot to the ground without blunting the instrument! Pursuing such a comparison, he rejected the idea of the bone belonging to the feline tribe at all. His attention was directed to another order, the paresseux or sloths, which have great toes and long nails. Their nails are folded up in a different fashion; they just enable the animal to walk; but slowly and awkwardly, something in the same manner as if we were to fold our fingers on the palm of the hand, and bear upon our knuckles. On instituting a more just comparison between these bones of the ancient animal, and the corresponding bones of the paresseux, he has satisfied us, that the lion of the American President was an animal which scratched the ground and fed on roots.

One experiences something like relief to find that there never

tive position of the two last bones is altered; so that the action of the flexor tendon can now draw forward the last bone—thus unsheathing and uncovering the claw, and preparing it to hold or to tear.

was such an enormous carnivorous animal as this, denominated megalonix.

These finger-bones, or bones of the claws, exhibit a very remarkable correspondence with the habits and general forms of animals. Besides what we have seen in the lion, or tiger, in the dog, and wolf, in the bear and ant-eater, there is a variety, where we should least expect it, in the animals that live in woods, and climb the branches of trees. The squirrel, with claws set both ways, runs with equal facility up and down the bole, and nestles in the angles of the branches. The monkey leaps and swings himself from branch to branch, and springing, parts with his hold by the hinder extremities before he reaches with the anterior extremities; he leaps the intervening space, and catches with singular precision. But the sloths do not grasp; their fingers are like hooks, and their strength is in their arms. They do not hold, but hang to the branch. They never let go with one set of hooks, until they have caught with the other, and thus they use both hind and fore feet, whilst their bodies are pendant. Here, once more, we see the form of the extremity, the concentration of strength, and the habit of animals, conforming not merely to their haunts in the forest, but to their mode of moving and living among the branches; all active, but in a different manner.

There have been of late deposited in our Museum in the College of Surgeons, the bones of an animal of great size; and the examination of these gives us an opportunity of applying the principles and the mode of investigation followed by our great authority in this part of science.

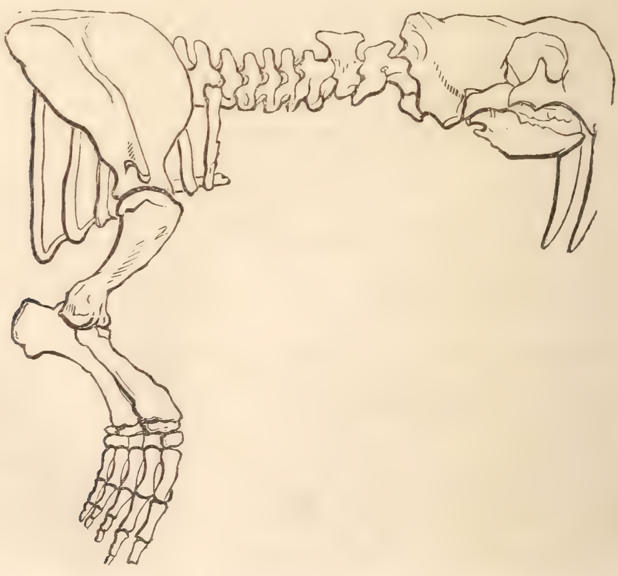
These remains consist of part of the head, spine, tail, pelvis, and the bones of one hinder extremity, and the scapula. Estimating the animal at seven feet in height, it scarcely conveys an adequate idea of its size; for the thigh-bone is three times the diameter of that of the large elephant which is in the same collection, and the pelvis is twice the breadth of that of the same animal. Forming our opinion on these principles to which we have had repeated occasion to refer in this essay, and judging by the strength and prominence of the processes of these bones, the animal must have possessed great muscular power; and directed by the same circumstances still, we can form an idea of the manner in which that muscular power was employed.

On comparing these bones with the drawings of the skeleton of the enormous animal preserved in the Royal Museum of Madrid, it is seen at once that this new acquisition is part of the remains of the great animal of Paraguay, the Megatherium of Cuvier. Every observation which we are enabled to make on the extreme bones of the foot, on the scapula, and on the teeth, confirms the idea entertained by Cuvier, that it was a vegetable feeder; and that its great strength was employed in flinging up the soil and digging for roots.

Its strength seems to have been concentrated to its paws, corresponding with the provisions there for enormous nails or claws. I have heard it surmised that this animal may have sat upon its hinder extremities, and pulled down the branches of trees to feed upon. It is only its great size that can countenance such an idea. We have not the humerus, which by its processes would have declared the classification and activity of its muscles; but we can estimate the height, breadth, and strength of the animal by the pelvis and enormous bones of the posterior extremity; while by the scapula and clavicle we can form a conception of the extent of motion of the anterior extremity, and the great power that it possessed. In short, by the osseous and muscular systems we perceive that the strength was not so much in the body, certainly not in the jaws, but was directed rather to the extremities; and that it was given neither for rapidity of motion nor defence, but for digging.

How little was it to be expected that an alliance between anatomy, the most despised part of it, and mineralogy, was to give rise to a new science;—making a part of natural history which had been pursued in mere idleness, vaguely, and somewhat fancifully, to be henceforth studied philosophically, and by inductive reasoning. It is both interesting and instructive to find the relations thus established between departments of knowledge apparently so remote.

In the true Amphibia, as the phoca and walrus, we have the feet contracted, and almost enveloped in the skin, and the fingers webbed and converted into fins.

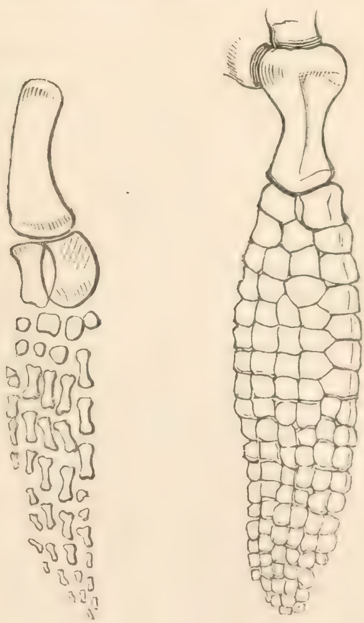


We have sketched here, the bones of the morse, or walrus, and they are remarkably complete, if we consider the appearance of the feet in the living animal. The bones are here accommodated to an instrument for swimming; for these animals live in the water, and come to land only to suckle their young, or to bask in the sun; and they are the most unwieldy and helpless, out of the water, of the all animals which breathe.

In the Cetacea, we have mammalia without hind feet. The scapula is large, the humerus very short, and the bones of the fore-arm and hand flattened and confined in membranes which convert them into a fin. They live in the water, but must rise to breathe.

I need not say that in the dolphin we recognise the bones of the anterior extremity, only a little further removed from the forms which we have hitherto been contemplating. The seal and morse raise themselves out of the water and lie on the rocks; the different species of the dolphin continue always in the water; the extremity is now a fin or an oar, and those who have seen the porpoise or the pelloch in a stormy sea, must acknowledge how complete the apparatus is, through which they enjoy their element.

The last examples I select, shall be from the ancient world.*



* The figure to the left is the anterior extremity of the Plesiosaurus; to the right that of the Ichthyosaurus. In these paddles we see the intermediate changes

These figures are taken from specimens in the College of Surgeons, of fossil animals of singular structure, between the crocodile and the fish. They are in a calcareous rock, and the skeletons are entire, but crushed, and a good deal disfigured. Here are the extremities or paddles consisting of a multitude of bones articulated; and among these we still discover the humerus, radius and ulna, and bones of the carpus and fingers. No fault is to be found with the construction of these instruments; they are suited to their offices, and no bone is superfluous, or misplaced, or imperfect. The ichthyosaurus and plesiosaurus (the animals which offer these specimens) inhabited the sea; the remains are found low in the lias deposite; great changes have been wrought on the land and on the deep since they existed; and the race of animals, the structure of whose extremities we have been engaged in examining, were not then in being. When we discover the same series of bones in the animals of the old world, we admit the existence of the same system; and we must necessarily acknowledge the progressive developement of that system, through a period of time incalculably remote; even if, instead of our days and years, referable to history, each day were as a thousand years, or we were to make our estimate by the records of the revolutions which have left their traces on the globe itself.

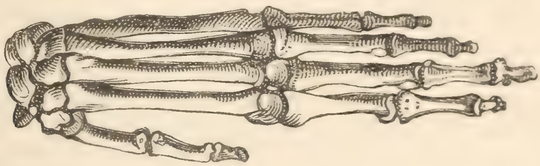
I have now given, I hope, sufficient examples of the changes in the bones of the anterior extremity, which suit them to every possible variety of use. After a little attention to the form of the human hand, I shall take up another division of my subject.

The motions of the fingers do not merely result from the action of the large muscles which lie on the fore-arm—these are for the more powerful actions; but in the palm of the hand, and between the metacarpal bones, there are small muscles (*Lumbricales and Interossei*), which perform the finer motions, expanding the fingers and moving them in every direction, with great quickness and delicacy. These are the organs which give the hand the power of spinning, weaving, engraving; and as they produce the quick motions of the musician's fingers, they are called by the anatomist *fidicinales.* Attention to our most common actions will show us, how the division into fingers, by combining motion with the sense of touch, adapts the hand to grasp, to feel, and to compare. We

from the foot of land animals to the fin of the fish.—The walrus, dolphin, turtle, plesiosaurus, ichthyosaurus—where we no longer find the phalanges or attempt to count the bones. They become irregular polygons or trapezoids—less like the phalanges than the radii of the fins of a fish. In fishes the anterior extremity is recognised in the thoracic fin; and we may even discover the prototypes of the scapula and the bones of the arm. I know not what the naturalist, who likes to note the gradual decrease of the elementary parts, makes of these hundred bones of the paddle or of the fin; where there is an increase of the number, whilst, relatively speaking, there is a defect of form and motion, of the parts.

shall presently see how well the points of the fingers are provided for feeling: as the joints and numerous muscles of the hand are adapted for various, distinct, or separate motions.

In this sketch we have the bones of the paw of the adult Chimpanzee, from Borneo; and the remarkable peculiarity is the smallness of the thumb; it extends no further than to the root of the fingers. On the length, strength, free lateral motion, and perfect mobility of the thumb, depends the power of the human hand.* The thumb is called *pollex*, because of its strength; and that strength is



necessary to the power of the hand, being equal to that of all the fingers. Without the fleshy ball of the thumb, the power of the fingers would avail nothing; and, accordingly, the large ball, formed by the muscles of the thumb, is the distinguishing character of the human hand, and especially of that of an expert workman.†

In a French book, intended to teach young people philosophy, the pupil asks why the fingers are not of equal length? The form of the argument reminds us of the difficulty of putting natural questions—the fault of books of dialogue. However, the master makes the scholar grasp a ball of ivory, to show him that the points of the fingers are then equal! It would have been better had he closed the fingers upon the palm, and then have asked whether or not they corresponded. This difference in the length of the fingers serves a thousand purposes, adapting the hand and fingers, as in holding a rod, a switch, a sword, a hammer, a pen, or pencil, engraving tool, &c., in all which, a secure hold and freedom of motion are admirably combined. Nothing is more remarkable, as forming a part of the prospective design to prepare an instrument fitted for the various uses of the human hand, than the manner in which the delicate and moving apparatus of the palm and fingers is guarded. The power with which the hand grasps, as when a sailor lays hold to raise his body in the rigging, would be too great for the texture of mere tendons, nerves, and vessels: they would be crushed, were not every part that bears the pressure, defended with a cushion of fat, as elastic as that which we have described in the foot of the horse and the camel. To add to this purely passive defence, there is a muscle which runs across the palm and more especially supports the cushion on its inner

* The monkey has no separate *flexor longus* of the thumb. Vicq. d'Azyr.
† "*Manus parva, majori adjutrix.*" Albinus.

edge. It is this muscle which, raising the edge of the palm, adapts it to lave water, forming the cup of Diogenes.

In conclusion,—what says Ray,—"Some animals have horns, some have hoofs, some teeth, some talons, some claws, some spurs and beaks; man hath none of all these, but is weak and feeble, and sent unarmed into the world—Why, a hand, with reason to use it, supplies the use of all these."

CHAPTER IV.

OF THE MUSCLES.

The muscle of the body is that fleshy part, with which every one is familiar. It consists of fibres which lie parallel to each other. This fibrous, or filamentous part, has a living endowment, a power of contraction and relaxation, termed irritability. A single muscle is formed of some millions of these fibres combined together, having the same point of attachment or origin, and concentrating in a rope or tendon, which is fixed to a moveable part, called its insertion. We may demonstrate upwards of fifty muscles of the arm and hand, all of which must consent to the simplest action; but this gives an imperfect view of the extent of the relation of parts which is necessary to every act of volition. We are most sensible of this combination in the muscles, when inflammation has seized any of the great joints of the body; for even when in bed every motion of an extremity gives pain, through the necessity of a corresponding movement in the trunk. When we stand, we cannot raise or extend the arm without a new position of the body, and a poising of it, through the action of a hundred muscles.

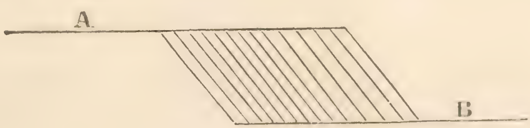
ON THE ACTION OF THE MUSCLES OF THE ARM.

We shall consider this subject under two heads; in the first, we shall give examples of the living property of the muscles; and then of the mechanical contrivances, in their form and application. In all that regards the muscles, we see the most bountiful supply of power commensurate to the object, but never anything in the least degree superabundant. If the limb is to be moved by bringing a muscle, or a set of muscles into action, the power is not given in that excess which would enable them to overcome their opponents; but the property of action is withdrawn from the opponents; they become relaxed, and the muscles, which are in a state of contraction, perform their office with comparative ease. A stationary con-

dition of the limb results from a balanced but regulated action of all the muscles; which condition may be called their tone. If, in an experiment, a weight be attached to the tendon of an extensor muscle, it will draw out that muscle to a certain degree, until its tone or permanent state resists the weight: but if the flexor muscle be now excited, this being the natural opponent of the extensor, the weight will fall, by the relaxation of the extensor. So that the motion of a limb implies an active state or a change in both classes of muscles, the one to contract, the other to relax; and the will influences both classes. Were it not so regulated, instead of the natural, easy, and elegant motions of the frame, the attempt at action would exhibit the body convulsed, or, as the physicians term it, in clonic spasms. The similitude of the two sawyers, mentioned by Paley, gives but an imperfect idea of the adjustment of the two classes of muscles. When two men are sawing a log of wood, they pull alternately, and when the one is pulling, the other resigns all exertion. But this is not the condition of the muscles—the relaxing muscle has not given up all effort, like a loose rope, but it is controlled in its yielding, with as fine a sense of adjustment, as is the action of the contracting muscles. Nothing appears to us more simple than raising the arm, or pointing with the finger; yet in that single act, not only are innumerable muscles put into activity, but as many are thrown out of action, and the condition of these classes is totally opposite to each other, under the same act of volition.

By such considerations, we are prepared to admire the faculty which shall combine a hundred muscles so as to produce a change of posture or action of the body; and we now perceive that the power taken from one class of our muscles, may be considered as if it were bestowed on the other; so that the property of life, which we call the irritability, or action of a muscle, is upon the whole, less exhausted than would be the case on any other supposition.

As to the second head, our demonstration is of an easier kind. We have said that nature bestows abundantly, but not superfluously; a truth evinced in the arrangement of the muscles. All the muscles of the limbs have their fibres running in an oblique direction,—thus, A. being the tendinous origin of a muscle, and B. the tendinous insertion, the fleshy fibres run obliquely between these two tendons.



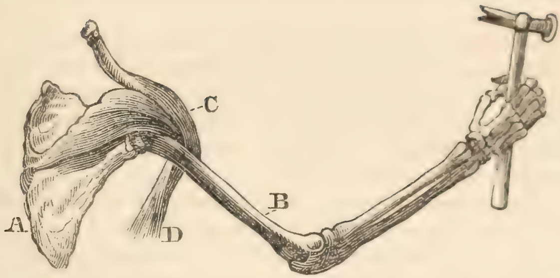
The fibre acting thus obliquely loses power, but gains the property of pulling what is attached to its further extremity through a greater space, while it contracts. This mechanical arrangement is intelli-

gible on the law, that velocity of motion through space, is equal to power or weight. Here in the muscle, there is a resignation of power to obtain velocity of motion.

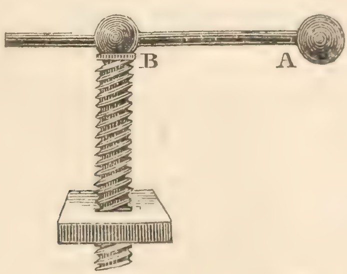
The same effect is produced by the manner in which the tendons of the muscles run over the joints. They would act more powerfully, if they went in a straight line to the toes or tips of the fingers: but by being laced down in sheaths, they move the toes and fingers with a velocity proportioned to their loss of power. Let us see how far this corresponds with other mechanical contrivances. A certain power of wind or water being obtained, the machinery is moved; but it is desired to give a blow, with a velocity far greater than the mo ion of the water or the turning of the wheels. For this purpose a fly-wheel is put on, the spokes of which may be considered as long levers. The wheel moves very slowly, at first, but being once in motion, each impulse accelerates it with more and more facility; at length, it acquires a rapidity, and a centrifugal force which nothing can equal in its effects, but the explosion of gunpowder. The mechanist not having calculated the power of the accelerated motion in a heavy wheel, has seen his machinery split and burst up, and the walls of the house blown out as by the bursting of a bomb-shell. A body at rest receives an impulse from another, which puts it into motion—it receives a second blow; now, this second blow has much greater effect than the first—for the power of the first was exhausted in changing the body from a state of rest to that of motion—but being in motion when it receives the second blow, the whole power is bestowed on the acceleration of its motion; and so on, by the third and fourth blows, until the body moves with a velocity, equal to that of the body from which the impulse is originally given. The slight blow given to a boy's hoop is sufficient to keep it running; and just so the fly-wheel of a machine is kept in rapid action by a succession of impulses, each of which would hardly put it in motion. If we attempt to stop the wheel, it will give a blow in which a hundred lesser impulses are combined and multiplied.

There is, in the machinery of the animal body, in a lesser degree, the same interchange of velocity and force. When a man strikes with a hammer, the muscle near the shoulder,* c. acts upon the humerus, B. in raising the extended lever of the arm and hammer, with every possible disadvantage; seeing that it is inserted or attached so near the centre of motion in the shoulder joint.

* A. The scapula, or shoulder blade: B. the humerus, or arm-bone; C. the deltoid muscle of the shoulder, arising from the shoulder-blade and clavicle, and inserted into the arm-bone; D. a muscle which draws the arm down, as in striking with a sword or hammer.



But the loss of power is restored in another form. What the muscle D. loses by the mode of its insertion, is made up in the velocity communicated to the hammer; for in descending through a large space, it accumulates velocity, and velocity is equal to force.—The advantage of the rapid descent of a heavy body is, that a smart blow is given, and an effect produced which the combined power of all the muscles, without this mechanical distribution of force, could not accomplish. This is, in truth, similar to the operation of the fly-wheel, by which the gradual motion of an engine is accumulated in a point of time, and a blow is struck capable of crushing or of stamping a piece of gold or silver. In what respect does the mechanism of the arm differ from the engine with which the printer throws off his sheet? Here is a lever with a heavy ball at the end; in proportion to its weight, it is difficult to be put in motion. The printer, therefore, takes hold of the lever near the ball, at A. Were he to continue pulling at that part of the lever, he would give to the ball no more velocity than that of his hand: but having put the ball in motion, he slips his hand down the lever to B. He could not have moved the weight, had he applied his hand



here at first; but it being now in motion, the whole strength of his arm is given to the lever at B., whilst the velocity of the great weight at the further end is accelerated. Thus the weight and the velocity being combined, the impulse given to the screw is much greater

than if he had continued to pull upon the further end of the lever at A.

If we now turn our eye to the diagram (page 65,) we shall understand that the muscle c. raises the long lever of the arm at a disadvantage, or very slowly; but the arm being moved, that motion is rapidly increased by each successive impulse from the muscle; and, of course, the velocity of the further extremity is more rapid than at the insertion of the tendon.

Again, if we consider the action of the muscle D. in pulling down the arm, as in giving a back stroke with the sword, we have the combination of two powers,—weight and muscular effort. When the hammer descends, the rapidity is increased by the mere effect of gravity; but when the action of the muscle is conjoined, the two forces, progressively increasing, greatly augment the velocity of the descent.

The same interchange of power for velocity, which takes place in the arm, adapts a man's hand and fingers to a thousand arts, requiring quick or lively motions. The fingers of a lady, playing on the pianoforte, or the compositor with his types, are instances of the advantage gained by this sacrifice of force for velocity of movement. The spring of the foot and toe is bestowed in the same manner, and gives elasticity and rapidity in running, dancing, and leaping.

After the many illustrations from mechanics which we have offered, the muscular power itself must be a subject of surprise and admiration. Gravity, the running of water, the expansion and condensation of steam, the production of gases, the spring or elasticity of material, or all these combined, could not have answered the varied offices performed by this one property of life possessed by the muscles. The irritable and contractile fibre, matter which, chemically considered, does not differ from the fibrine of the blood, being endowed with this property of contraction, and adapted with "mechanical ingenuity," fulfils a thousand distinct purposes, in volition, breathing, speaking, in digestion, assimilation, circulation; and in all these it is modified to the wants and condition of every class of animals.

From what the reader already understands of the conformity which subsists among all the parts of an animal body, he will readily comprehend that there is a perfect relation between the bones and the muscles: that as the bones change, and exhibit a variety in their size, relative position, and articulations, so there is an adaptation of the muscles. We sometimes find them separated into smaller muscles, and sometimes consolidated into more powerful masses.

The demonstration to the anatomical student of the muscles of the human hand and arm, becomes the test of his master's perfection as a teacher. Nothing is more uninteresting, tedious, and difficult to attend to, than the demonstration of the muscles of the arm, when they are taken successively, as they present themselves; but when

they are taught with lucid arrangement, according to the motions performed by them, it is positively agreeable to find how much interest may be given to the subject.

It would be foreign to the object of this work to introduce such demonstrations here.

Yet it is very remarkable that the muscles of the arm and hand should resemble so closely the muscles of the fore extremity of the lion, for example. The flexors, extensors, pronators, and supinators are, in the brute, exactly in the same place, and bear all the relations which the student of anatomy is taught to observe with so much interest in the human arm. This example is sufficient to show how accurately the comparative anatomy of the muscles conforms to that of the bones; and that in proportion as the bones of the extremity resemble in shape and power of motion those of the human arm, so do the muscles—another proof of the great extent of the system of relations established in the animal system.

There is one circumstance more which should not be omitted in the comparative anatomy of these muscles, as it exhibits another instance of conformity in their structure, to the offices which they have to perform. We have just stated that the power of contraction is a vital property. The continued action of a muscle, therefore, exhausts the vitality; and to support that action, when it is inordinate, there must be a more than usual provision for the supply of this living power, viz:—a means of increasing or perpetuating the circulation of the blood, which is the source of all vital power.

In the *lemur tardigradus* it has been observed that the axillary and femoral arteries, the great arteries of the anterior and posterior extremities, have this peculiarity—that the trunk is subdivided into a number of equal-sized cylinders, which again unite to form a single trunk previous to the distribution of its branches to the muscles.* It has been argued that this peculiarity, as it produces a retardation of the blood, is adapted to a long continued action in the muscles. I believe it to be a provision for long continued action; because the animals which possess it, are not more remarkable for the slowness of their progression than for the tenacity of their hold. The extremities are long and the muscles powerful, either to sustain the animal by grasping the branches of trees, or for digging: but surely the strength of the muscles cannot be produced by retardation of the circulation, on the principle, universally admitted, that the expenditure of arterial blood is in proportion to the vital force employed.

Were the arteries of the living body like rigid tubes, and the laws of the circulation the same as those of hydraulics, such might be the conclusion. But it is impossible to suppose that the circulation of the blood could be performed according to the laws which govern the flow of water in dead tubes. The artery is dilatable, it contracts with a vital force; both the dilatability and the contractility of arte-

* There is some doubt as to the reunion of the vessels.

ries are subject to the influences of the living principle. When, therefore, the artery of a limb is divided into four or five vessels, the result is a greater capacity of dilatation, a greater power of contraction; and these being vital operations, are subject to be influenced and adjusted according to the necessity for the increase or diminution of the circulation.

If such a peculiarity in the form of the vessels in the extremities of these animals, retards the blood, it can only be during repose; for, on excitement, so far from retarding, it must bestow remarkable power of acceleration. I conclude, therefore, that this variety of distribution in the arteries is a provision for occasional great activity in the muscles of the limb, and for forcing the blood into contact with the fibres, notwithstanding their continued action and rigidity.

We have seen in the preceding chapter the same organ, which moves at one time as slowly as the hand of a watch, at another moves with extreme rapidity; consequently, we cannot admit the inference that the tortuous and subdivided artery is a provision for languid motions.

In speaking of the arteries which go to the hand, it may be expected that we should touch on a subject, which has been formerly a good deal discussed, whether the properties of the right hand, in comparison with those of the left, depend on the course of the arteries to it. It is affirmed that the trunk of the artery going to the right arm, passes off from the heart so as to admit the blood directly and more forcibly into the small vessels of the arm. This is assigning a cause which is unequal to the effect, and presenting, altogether, too confined a view of the subject; it is a participation in the common error of seeking in the mechanism the cause of phenomena which have a deeper source.

For the conveniences of life, and to make us promp and dexterous, it is pretty evident that there ought to be no hesitation which hand is to be used, or which foot is to be put forward; nor is there, in fact, any such indecision. Is this taught, or have we this readiness given to us by nature? It must be observed, at the same time, that there is a distinction in the whole right side of the body, and that the left side is not only the weaker, in regard to muscular strength, but also in its vital or constitutional properties. The developement of the organs of action and motion is greatest upon the right side, as may at any time be ascertained by measurement, or the testimony of the tailor or shoemaker; certainly, this superiority may be said to result from the more frequent exertion of the right hand; but the peculiarity extends to the constitution also; and disease attacks the left extremities more frequently than the right. In opera dancers, we may see that the most difficult feats are performed by the right foot. But their preparatory exercises better evince the natural weakness of the left limb, since these performers are made to give double practice to it, in order to avoid awkwardness in the public exhibition; for if these exercises be neglected, an ungraceful preference will be

given to the right side. In walking behind a person, it is very seldom that we see an equalized motion of the body; and if we look to the left foot, we shall find that the tread is not so firm upon it, that the toe is not so much turned out as in the right, and that a greater push is made with it. From the peculiar form of woman, and the elasticity of her step resulting more from the motion of the ankle than of the haunches, the defect of the left foot when it exists, is more apparent in her gait. No boy hops upon his left foot, unless he be left handed. The horseman puts the left foot in the stirrup and springs from the right. We think we may conclude, that everything being adapted in the conveniences of life to the right hand, as for example the direction of the worm of the screw or of the cutting end of the auger, is not arbitrary, but is related to a natural endowment of the body. He who is left handed is most sensible to the advantages of this adaptation, from the opening of the parlour-door to the opening of a pen-knife. On the whole, the preference of the right hand is not the effect of habit, but is a natural provision, and is bestowed for a very obvious purpose: and the property does not depend on the peculiar distribution of the arteries of the arm—but the preference is given to the right foot, as well as to the right hand.

CHAPTER V.

THE SUBSTITUTION OF OTHER ORGANS FOR THE HAND.

After having examined the manner in which one instrument, the hand, is modified and adapted to a variety of purposes in different animals, there remains only this mode of elucidation—that we contrast it with its imperfect substitutes in other creatures. I might, indeed, have shown in the insect tribes the most curious examples of instruments for similar purposes with the hand and fingers of man: but I have intentionally confined this inquiry to the higher classes of animals.

The habits of some fishes require that they should cling firmly to the rocks or to whatever presents to them. Their locomotive powers are perfect; but how are they to become stationary in the tide or the stream? I have often thought it wonderful that the salmon or the trout, for example, should keep its place, night and day, in the rapid current. In the sea, there are some fishes especially provided with means of clinging to the rocks. The lump-fish, *cyclopterus lumpus* fastens itself by an apparatus which is on the lower part of its body. The sucking-fish, *remora*, has a similar provision on its back. It attaches itself to the surface of the shark and to whatever is afloat;

and, of course, to the bottoms of ships. The ancients believed it capable of stopping a ship under sail, and Pliny, therefore, called it remora. We must admire the means by which these fishes retain their proper position in the water, without clinging by their fins or teeth, and while they are free for such efforts as enable them* to seize their food. The apparatus by which they attach themselves resembles a boy's sucker: the organ being pressed against the surface to which the creature is to be fixed, the centre is drawn by muscles in the same manner that the sucker is drawn with the cord, and thus a vacuum is made.

In the cuttle-fish we see a modification of this apparatus: the suckers are on the extremities of their processes or arms, and become instruments of prehension and of locomotion. They are capable of turning in all directions, either to fix the animal or to drag it from place to place. In the Indian Seas, these creatures become truly terrific from the length of their arms, which extend to eight or nine fathoms, and from the firmness with which they cling.

Dr. Shaw tells us, that on throwing a fish of the species cyclopterus lumpus into a pail of water, it fixed itself so firmly to the bottom, that by taking hold of the tail, he lifted up the pail, although it contained some gallons of water.

There is another fish, which from its name we should expect to perform strange antics; it is called harlequin angler.† Its appearance is grotesque and singular; the pectoral fins resemble short arms, and are palmated at their tips.‡ M. Renau, in his history of fishes, affirms that he knew an individual of this species; and the expression is not so incorrect, since he saw it for three days out of the water, walking about the house in the manner of a dog. The circumstance of its walking out of the water has some interest, as showing relations between organs which are apparently the least connected. The fact of this fish living out of the water is doubted; but the form of its branchial organs inclines me to believe it; and its habits require such a provision. In this genus, the operculum does not open to let the respired water pass off freely behind, as in most fishes; but the water is discharged by a small aperture which, in Mr. Owen's opinion, is capable of being closed by a sphincter. The cavities in

* In the Mollusca and Zoophytes we find many instances of the animal holding on against the force of tide or current. The Actiniæ fix themselves to rocks and shells; and some, as the sea carnation, hang suspended from the lower surface of projecting rocks, resembling the calyx of a flower. By the elongation of their tentacula, they expand and blow out like a flower; but instead of petals, these are prehensile instruments by which they draw whatever food floats near them into their stomachs. The Byssus of the muscle is a set of filaments which retains the shell at anchor and prevents it drifting or rolling with the tide. These filaments are the secretion of a gland, and whilst they are fixed to the rock, the gland retains the hold at their other ends. The shell of the oyster is itself cemented to the rock.

† *Lophius Histrio*, from a Greek word that has reference to the process which floats from the head, like a streamer or pennant.

‡ These fins have two bones in them like the radius and ulna; but Cuvier says, that they are more strictly bones of the carpus.

which the branchiæ lie, are large, and this is, indeed, partly the reason of the monstrous head of this fish. Thus, it has not only its fins converted into feet, but its gills into pouches, capable of containing water, and of permitting the function of the branchiæ to proceed when the water is retired; that is, when it lies in mud, or shallow pools; for in such situations does the lophius find its food, where it angles for it in a very curious manner.

But there are other fishes that move out of the water on dry land, and even ascend trees, without being carried there by floods. The *perca scandens*, by means of the spines of its gill-covers, and the spinous rays of its fins, climbs trees; so that Dr. Shaw calls it the climbing fish.*

All creatures which have their skins protected, whether by feathers, or shells, or scales, have an exquisite touch in their mouth, or in the appendages which hang from it. Fishes have *cirri* which hang from their mouth, and these are equivalent to the palpa and tentacula of insects and crustacea. The fishing lines of the *lophusi piscatorius* are examples of these processes: and Pliny relates that this frog-like fish, hiding in the mud, leaves the extremities of these filaments visible; which, from their resemblance to worms, entice the smaller fishes, and they become the prey of their concealed enemy. It is surprising how varied their means are by which fishes obtain their food. The *chætodon* (bandouliere à bec) squirts water at flies as they pass and brings them down. The *sciæna jaculatrix*, according to Pallas, has a similar power; and the *sparus insidiator* catches aquatic insects by the sudden projection of its snout. It is affirmed by some naturalists that the rays of the dorsal and anal fins, as in the cordonnier of Martinique, *zeus ciliaris*, le blepharis, Cuv., are employed to grapple or coil round the stems of plants and sustain the fish.

The several offices attributed to these processes in fishes imply that they possess sensibility, if not muscular power.

By anatomical investigation and experiment, I, some years ago, discovered that the sensibility of all the head and of its various appendages resulted from one nerve only of the ten which are enumerated as arising from the brain, and are distributed within and around the head; and, pursuing the subject by the aid of comparative anatomy, I found that a nerve corresponding to this, which is the fifth nerve in man, served a similar purpose in all the lower animals. In creatures which are covered with feathers or scales, or protected by shell, this nerve becomes almost the sole organ of sensibility. It is the developement of this nerve which gives sensibility to the cirri, which hang about the mouths of fishes, and to the palpa of the crustacea and insects. It is the same nerve which supplies the tongue, and is the organ of its exquisite sensibility to touch, as

* The spines of the Echinus are moveable; they assist in progression. They are directed towards an advancing enemy! Although these spines may be effectual for their purpose they are the lowest or least perfect substitutes for the extremities.

well as of taste. In some animals, especially in the reptiles, the tongue, by its length and mobility, becomes a substitute for these external appendages. We might have noticed before, that the tongue is an organ of prehension as well as of touch. With it the ox gathers in the herbage; and in the giraffe, it is rather curious to observe that as the whole frame of the animal is calculated to raise the head to a great height, so is the tongue capable of projecting beyond the mouth to an extraordinary extent, to wrap round and pull down the extreme branches of trees. The whiskers of the feline quadrupeds possess a fine sensibility through branches of the fifth nerve, which enter their roots. Birds have a high degree of sensibility to touch in their mouths. In ducks, and all that quaffer with their bills under water, the sense is very fine, and we find, on dissection, that a branch of the fifth nerve, remarkably developed, is distributed on the upper mandible. Animals feel in the whole of their external surface; and we may say that serpents, by coiling themselves round a body, have the organ of touch all over them. Still the fifth pair of nerves in the head, or the nerve analogous to it, is the main instrument of touch in the greater number of animals where extremities are wanting. There are organs varying in their conformation, sometimes delicate palpa, sometimes horny rods, and these are often possessed of muscularity as well as sensibility; but to all, the sense of touch is bestowed through a nerve corresponding with the fifth pair, the nerve of the tongue and lips, and of the muscles of the jaws in man.

But we may repeat, that, necessary as these appendages and this sensibility are to the existence of these animals, their imperfections serve, by contrast, to show how happily the different properties are combined in the hand; in which we perceive the sensibilities to changes of temperature, to touch, and to motion, united with a facility in the joints of unfolding and moving in every possible degree and direction, without abruptness or angularity, and in a manner inimitable by any artifice of joints and levers.

CHAPTER VI.

THE ARGUMENT PURSUED FROM THE COMPARATIVE ANATOMY.

So far as we have hitherto proceeded, by examining objects in comparative anatomy which from their magnitude can not be misunderstood, we have been led to conclude that, independently of the system of parts marvellously combined to form the individual animal, there is another, more comprehensive system, which embraces all animals; and which exhibits a certain uniformity in the functions

of life, however different in form or bulk the creatures may be, or to whatever condition of the globe they may have been adapted. We have seen no accidental deviation or deformity, but that every change has been for a purpose, and every part has had its just relation. We have witnessed all the varieties moulded to such a perfect accommodation, and the alterations produced by such minute degrees, that all notion of external and accidental agency must be rejected.

We might carry our demonstration downward through the lower classes of animals; for example, we might trace the feet of insects from their most perfect or complex state, till they disappear; or, observing the changes in another direction, we might follow out the same parts from the smallest beginning to the most perfect condition of the member, where we see the thigh, leg, and tarsus of the fly.

We might distinguish them at first as the fine cirri, like minute bristles, which on the bodies of worms take slight hold of the surface over which they creep. In the sea-mouse, (*aphrodita*) we might notice these bristles standing out from distinct mammillary processes, which are furnished with appropriate muscles. Then in the *myriapodes*, the first order of insects, we might see the same "many feet," and each foot having a distinct articulation. From that, we might pass to the feet of those insects, where there is a thigh, leg, and foot, with the most perfect system of flexors, extensors, and adductor muscles, possessing, in fine, all that we most admire in the human anatomy. Nay, it is most curious to observe how the feet of the true insects are again changed or modified; taking new offices, the anterior feet becoming feelers, organs of prehension, or *hands*. When, with such an object, we view the delicate and curiously adapted instruments of insects, we must perceive that it would be easy to trace almost every part through a succession of modifications. Among the *vertebrata*, we have seen the hand become a wing or a fin; so might we trace the wings of insects. If we begin with a fly, which has two delicate and perfect wings incased and protected, we find that the covers are raised to admit the expansion of the wings. In another, the case becomes a wing; and the fly is characterized by four wings. Proceed to examine a third example, and we shall discover that this anterior wing is larger and more perfect than the posterior: the fourth specimen has lost the posterior wings, and has only two perfect ones; and if we continue the examination, the next specimen will present an insect deprived of wings altogether. These are not freaks of nature, but new forms of the body; new appendages required for a different poising of the fly in its flight. They are adaptations in that regular series which we have observed to obtain in the larger animals, and where the intention can not be mistaken. A very natural question will force itself upon us, how are those varieties to be explained?

The curious adaptation of a member to different offices and to different conditions of the animal has led to a very extraordinary

opinion in the present day,—that all animals consist of the same elements. It would be just to say that they consist of the same chemical elements, and that they attract and assimilate matter by the performance of the same vital functions, through every species of animals, however different in form and structure. But by the elements which are now mentioned, the authors of this new theory mean certain pieces which enter into the structure of the body, and which they illustrate by the analogy of the building materials of a house. If these materials, they say, are exhausted in the ornamental parts of the portico and vestibule, there must be a proportionate limitation of the apartments for the family!

This new theory has been brought forward with the highest pretensions; the authors of it have called upon us to mark the moment of its conception as the commencement of a new era! They speak of the "elective affinities of organs," "the balancing of organs," "a new principle of connexion," and a "new theory of analysis."—The hypothesis essentially is this, that when a part, which belongs to one animal, is missed in another, we are to seek for it in some neighbouring organ: and on such grounds they affirm, that this surpasses all former systems as a means of discovery. Now, the perfection or aggrandizement of any one organ of an animal is not attended with the curtailment or proportional deficiency of any other. Like ourselves, perhaps, the supporters of this theory dwell too much upon the bones; but even in them, we shall show that the system is untenable. In the mean time, we may ask, do additional parts connected with the stomach, making it highly complex, as in ruminating animals, shorten the intestinal canal, or make its form simpler? On the contrary, is not a complex stomach necessarily connected with a long and complicated intestine?—Does a complex intestinal canal throughout all its course render imperfect the solid viscera which are in juxtaposition to it? Is there any defect in them, because the organs of digestion are perfect, or complicated? Does the complex heart imply a more simple, or a more perfect condition of the lungs? In short, as animals rise in the scale of existence, do we not find that the systems of digestion, circulation, respiration and sensation, bear ever a proportional increase? Is there any instance of an improvement in one organ thrusting another out of its place, or diminishing its volume?

Now, as to the osseous system, were we to follow these theorists into the very stronghold of their position, the bones of the skull, where the real intricacy of the parts allows them some scope for their ingenuity, we might show how untenable the principle is which they assume. But we must confine ourselves to our own subject.

In the higher orders of the vertebrata, we find that the bones of the shoulder perform a double office; that they have an important

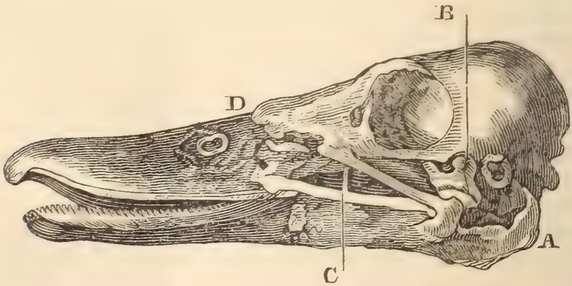
share in the act of respiration, whilst they are perfect as a foundation for the extremity. Now, let us take an instance where the mode of respiration of the animal is inconsistent with what we may term the original mechanism of the bones of the shoulder. In the batrachian order, the ribs are wanting: where then are we to look for them? Shall we follow a system which informs us that when a bone is wanting in the cavity of the ear, we are to seek for it in the jaw; and which, yet, shall leave us in the contemplation of this class of animals deficient in thirty-two ribs, without pointing out where they are to be found, or how their elements are built up in other structures? If, on the contrary, we take the principle that parts are formed or withdrawn, with a never-failing relation to the function which is to be performed, we see that no sooner are the compages of the chest removed, and the shoulder thus deprived of support, than the bones to which the extremity is fixed are expanded and varied, both in form and articulation, so as to fulfil their main object of giving security and motion to the arm.

With respect to the instance which we have accidentally noticed regarding the mechanism of the jaw in birds, and which is brought forward so vauntingly, as a proof of the excellence of the theory, it does, indeed, prove the reverse of what is assumed. The only effect of this hypothesis is to make us lose sight of the principle which ought to direct us in the observation of such curious structures, as well as of the conclusions to which an unbiassed mind would come. The matter to be explained is simply this:—the chain of bones in the ear, which is so curiously adapted in the mammalia to convey the vibrations of the membrane of the tympanum to the nerve of hearing, is not found in the organ of hearing in birds; but there is substituted a mechanism entirely different. They choose to say that the incus, one of the bones of the chain, is wanting in the bird. Where shall we find it?—they ask. Here it is in the apparatus of the jaw or mandible; in that bone which is called *os quadratum*. I believe that the slight and accidental resemblance which this bone (B.) in the bird has to the incus, is the real origin of this fancy. Let us follow a juster mode of reasoning, and see how this hypothesis obscures the beauty of the subject. The first step of the investigation ought to be to inquire into the fact, if there be any imperfection in the hearing of birds. That is easily answered—the hearing of birds is most acute; the slighest noise alarms; and the nightingale, or other bird of song, in a summer evening, will answer to the note of his rival, when he is out of our hearing. We have next to observe the imperfection in the organ—the want of an external ear; which, were it present, would be at variance with all that we have most to admire in the shape of the bird and the direction of the feathers, as conducing to its rapid passage through the air. With this obvious defect of the external ear, can we admit that the internal ear is also imperfect,

notwithstanding the very remarkable acuteness of hearing, which we know to result from this internal structure, and from it alone? Now we do, in fact, find a different structure in the ear of birds; but, yet nothing is wanting. The *columella* is a shaft of bone of exquisite delicacy, which is extended from the outward membrane of the ear to the labyrinth or proper seat of the nerve of hearing. It occupies the place and office of the chain of four bones which belong to the ear of mammalia. We have no authority, however, for affirming that the incus is here wanting more than any other bone of the chain;—and if it be said that the os quadratum is the missing incus, why should not we find in the oviparous reptiles, where there is a *columella* in the ear, an os quadratum in the jaw?

From this mode of inquiry, we find that the sense of hearing is enjoyed in an exquisite degree in birds: that the organ of the sense is not imperfect, but is adapted to a new construction, and a varied apparatus—suited to the condition of the bird: and that there is no accidental dislocation or substitution of something less perfect than what we find in other classes of animals.

If we now look to the structure of the mandible of the bird, we shall find as curious, though a somewhat grosser example of mechanical relation. The bill of the bird, in some degree, pertains to our subject, as it is the organ of prehension and of touch. It is withal a fly trap—hence, its motions must be rapid: and the velocity is increased by the most obvious means imaginable,—that is, by giving motion to both mandibles, instead of to one. When a dog snaps he throws back his head, and thereby raises the upper jaw at the same time that the lower jaw is dropped; but these are slow and clumsy motions, pertaining to the muscles of the neck as well as of the jaws, and the poor hound makes many attempts before he catches the fly that teazes him. But a swallow or fly-catcher makes no second effort, so admirably suited is the apparatus of prehension to the liveliness of the eye and the instinct. The adaptation of the instrument consists in this, that the



muscles which open the lower mandible, by the same effort, open the upper one: A. is a process of the lower mandible, projecting

much behind the centre of motion, and the muscle which is attached to it opens the bill;—but at the same time, the lower mandible presses upon the bone B., the *os quadratum:* now, there is attached to this bone, projecting forwards, with its anterior extremity fixed against the upper mandible, a shaft or process of bone C.; and this receives the pressure of the *os quadratum*, when the muscle acts; so that being thrust forwards, like a bolt, it opens the upper mandible, which moves upon the skull at D. Here, then, is a piece of mechanism as distinct as the lock of a gun, which is for the purpose, as we have said, of giving rapidity to the motions of the bill. Is it nearer the truth to consider this as a new apparatus, suiting the necessities of the creature, or an accidental result of the introduction of a bone, which in its proper office has nothing to do with the jaw?

But we have wandered somewhat from our subject. We have taken the bones of the shoulder, or those of the extremity which are nearest to the trunk; we may pursue the inquiry by noticing those which are most romote from it. In the bones of the hand, we have seen that the same system was variously modified so as to be adapted to every possible change in office. But as it is insisted that the number of parts continue the same, what can we say to the bones of the paddle in the saurian and chelonian tribes, which, as in the ichtyosaurus for example, consist of sixty or seventy polygonous bones; whilst in the horse there are only fifteen bones; and in man, twenty-seven. Yet, with all those bones in the paddle, there is still the full complement in the part that corresponds with the arm. If the system fails us in such an obvious instance as this, with what confidence can we prosecute the intricate bones of the spine and head under its guidance?

Seeking assistance from the works of distinguished naturalists, we do not always find that disposition of mind prevail, which we should be apt to suppose a necessary result of their peculiar studies. We do not discover that combination of genius with sound sense, which distinguished Cuvier, and the great men of science. It is, above all, surprising with what perverse ingenuity men seek to obscure the conception of a Divine Author, an intelligent, designing, and benevolent Being—rather clinging to the greatest absurdities, or interposing the cold and inanimate influence of the mere elements, in a manner to extinguish all feeling of dependence in our minds, and all emotions of gratitude.

Some will maintain that all the varieties which we see, are the result of a change of circumstances influencing the original animal; or that new organs have been produced by a desire and consequent effort of the animal to stretch and mould itself—that, as the leaves of a plant expand to light, or turn to the sun, or as the roots shoot to the appropriate soil, so do the exterior organs of animals grow and adapt themselves. We shall presently find that an

pinion has prevailed that the organization of animals determines their propensities; but the philosophers, of whom we are now speaking, imagine the contrary,—that under the influence of new circumstances, organs have accommodated themselves, and assumed their particular forms.

It must be here remarked that there are no instances of the production of new organs by the union of individuals belonging to different species. Nor is there any foundation in observation for the opinion that a new species may be formed by the union of individuals of different families. But it is contended, that, although the species of animals have not changed in the last 5000 years, we do not know what might have been the effect of the revolution before that time; that is, previous to the present condition of the world. But, on subjects of this nature, we must argue from what we know, and from what we see.

We do perceive surprising changes in the conformation of animals; some of them are very familiar to us; but all show a foreknowledge and a prospective plan, an alteration gradually taking place in preparation for the condition, never consequent upon it. It will be sufficient for our purpose, if we take the highest and the lowest examples. Man has two conditions of existence in the body. Hardly two creatures can be less alike than an infant and a man. The whole fœtal state is a preparation for birth. My readers would not thank me, were I to show how necessary all the proportions and forms of the infant are to his being born alive,—and yet nothing is so easy to demonstrate. Every one may see that from the moment of birth there is a new impulse given to the growth, so as finally to adapt the proportions of the body to the state of perfect manhood. Few, however, are aware that the fœtus has a *life* adapted to its condition, and that if the confinement of the womb were protracted beyond the appointed time, it must die!—from no defect of nourishment, but simply, because the time is come for a change in its whole economy!

Now, during all the long period of gestation, the organs are forming; the lungs are perfected before the admission of air—new tubes are constructed before the flood-gates, which are to admit the blood, are opened. But there are finer, and more curious, provisions than these. If we take any of the grand organs, as the heart, or the brain, and examine it through all its gradations of change in the embryo state, we shall recognise it simple, at first, and gradually developing, and assuming the peculiarities which finally distinguish it. So that it is affirmed, and not without the support of a most curious series of observations, that the human brain, in its earlier stage, resembles that of a fish: as it is developed, it resembles more the cerebral mass of the reptile; in its increase, it is like that of a bird, and slowly, and only after birth, does it assume the proper form and consistence of the human encephalon.

But in all these changes to which man is subject, we nowhere see the influence of the elements, or any other cause than that it has been so predestined. And if, passing, over the thousand instances which might be gathered from the intermediate parts of the chain of animal existence, we take the lowest link, and look to the metamorphosis of insects, the conclusion will be the same.

For example, if we examine the larva of a winged insect, we shall see the provisions for its motion over the ground, in that condition, all admirably supplied in the arrangement of its muscles, and the distribution of its nervous system. But if, anticipating its metamorphosis, we dissect the same larva immediately before the change, we shall find a new apparatus in progress towards perfection; the muscles of its many feet are seen decaying; the nerves to each muscle are wasting; a new arrangement of muscles, with new points of attachment, directed to the wings instead of the feet, is now visible; and a new distribution of nerves is distinctly to be traced, accommodated to the parts which are now to be put in motion. Here is no budding and stretching forth under the influence of the surrounding elements; but a change operated on all the economy, and prospective, that is, in reference to a condition which the creature has not yet attained.

These facts countenance the conclusion drawn from the comparative anatomy of the hand and arm—that with each new instrument, visible externally, there are a thousand internal relations established: a mechanical contrivance in the bones and joints, which alters every part of the skeleton: an arrangement of muscles, in just correspondence: a texture of nervous filaments, which is laid intermediate between the instrument and the very centre of life and motion; and, finally, as we shall discover from what follows, new sources of activity must be created in relation to the new organ, otherwise the part will hang a useless appendage.

It must now be apparent that nothing less than the Power, which originally created, is equal to the effecting of those changes on animals, which are to adapt them to their conditions: that their organization is predetermined, and not consequent on the condition of the earth or the surrounding elements. Neither can a property in the animal itself account for the changes which take place in the individual, any more than for the varieties which take place in the species. Everything declares the species to have its origin in a distinct creation, not in a gradual variation from some original type; and any other hypothesis than that of a new creation of animals suited to the successive changes in the inorganic matter of the globe—the condition of the water, atmosphere, and temperature—brings with it only an accumulation of difficulties.

CHAPTER VII.

OF SENSIBILITY AND TOUCH.

We find every organ of sense, with the exception of that of touch, more perfect in brutes than in man. In the eagle and the hawk, in the gazelle and in the feline tribe, the perfection of the eye is admirable;—in the dog, wolf, hyena, as well as in birds of prey, the sense of smelling is inconceivably acute; and if we should have some hesitation in assigning a more exquisite sense of taste to brutes, we cannot doubt the superiority of that of hearing in the inferior animals. But in the sense of touch, seated in the hand, man claims the superiority; and it is of consequence to our conclusion that we should observe why it is so.

It has been said that, accompanying the exercise of touch, there is a desire of obtaining knowledge; in other words, a determination of the will towards the organ of the sense. Bichat says, it is active whilst the other senses are passive. This opinion implies that there is something to be understood—something deeper than what is here expressed. We shall arrive at the truth by considering that in the use of the hand there is a double sense exercised; we must not only feel the contact of the object, but we must be sensible to the muscular effort which is made to reach it, or to grasp it in the fingers. It is in the exercise of this latter power that there is really an effort made; there is no more direction of the will towards the nerve of touch, than towards any other sensible nerve. But, before entering on the consideration of the sensibility and action which belong to the fingers, we must attend to the common sensibility of the surface.

Besides that the common sensibility belongs to the hand, and that some inquiry into it is necessary to the completion of our subject, I pursue it the more willingly, because there is no other which affords more surprising proofs of design and of benevolence in the Author of our being. However obvious the proofs may be which are drawn from the mechanism of the body, they are not to be compared with, in this respect, to those which are derived from the living endowments of the frame.

I have used the term common sensibility in conformity with the language of authors and with customary parlance; but the expressions, the "common nerves," and the "common sensibility," in a philosophical inquiry, are inadmissible. Indeed, these terms have been the cause of much of the obscurity which has hung over the subject of the nervous system, and of our blindness to the benevolent adaptation of the endowments of that system to the condition of animal existence. Thus, it has been supposed that

some nerves are more coarsely provided for sensation, and that others are of a finer quality, adapted to more delicate impressions. It is assumed that the nerve of the eye is finer than the nerve of the finger—without considering that the retina is insensible to that quality of matter of which we readily acquire the knowledge through touch. Nerves are, indeed, appropriated to peculiar senses, and to the bestowing of distinct functions, but delicacy of texture has nothing to do with this. The nerve of touch in the skin is insensible to light or to sound, not because it has a coarser or more common texture: The beauty and perfection of the system is, that the nerve is made susceptible to its peculiar impression only. The nerve of the skin is alone capable of giving the sense of contact, as the nerve of vision is confined to its own office. If this appropriation resulted merely from a more delicate texture: if the retina were sensible to the matter of light only from possessing a finer sensibility than the nerve of touch, it would be a source of torment; whereas it is most beneficently provided that it shall not be sensible to pain, nor be capable of conveying any impressions to the mind, but those which operate according to its proper function, producing light and colour.

The pain which we experience in the eye, and the irritation from dust, are owing to a distinct nerve from that of vision, and are consequent on the susceptibility of the surface to a different kind of impression; of which more presently. We should keep in mind the interesting fact, that when surgeons perform the operation of couching, the point of the needle, in passing through the outer coat of the eye, gives a sensation of pricking, which is an exercise of the nerve of touch; but when the point passes through the retina, which is the expanded nerve of vision and form the internal coat of the eye, the sensation that is produced is as of a spark of fire. The nerve of vision is as insensible to touch as the nerve of touch is to light.*

The extreme sensibility of the skin to the slightest injury conveys to every one the notion—that the pain must be the more severe the deeper the wound. This is not the fact, nor would it accord with the beneficent design which shines out every where. The sensibility of the skin serves not only to give the sense of touch, but it is a guard upon the deeper parts; and as they cannot be reached except through the skin, and we must suffer pain, therefore, before they are injured, it would be superfluous to

* The views of the nervous system, which are shortly given in the text, guided me in my original experiments made twenty-two years ago. They have been attributed to foreign physiologists. The ignorance of what has been done in England, may be, for strangers, an excuse for maintaining these opinions as their own; but the authors at home, who should have known what has been taught in this country, are inexcusable when they countenance these assumptions.

bestow sensibility upon these deeper parts. If the internal parts which act in the motions of the body had possessed a similar degree and kind of sensibility with the skin, so far from serving any useful purpose, this sensibility would have been a source of inconvenience and continual pain in the common exercise of the frame.

The reason why surgeons more than physicians have advanced the study of physiology, may be, that they become practically acquainted with the phenomena on which the science is founded. The surgeon who has to perform an operation by incision, when he has cut through the skin, informs his patient that the greatest pain is over. If, in the advanced stage of the operation, he has to extend the incision of the skin, it is very properly considered as a great awkwardness; and this not only because it proves that he has miscalculated what was necessary to the correct performance of his operation, but because the patient, bearing courageously the deeper incisions, cannot sustain the renewed cutting of the skin, without giving token of severe pain.

The fact of the exquisite sensibility of the surface, in comparison with the deeper parts, being thus ascertained by daily experience, we cannot mistake the intention: that the skin is made a safeguard to the delicate textures which are contained within, by forcing us to avoid injuries: and it does afford us a more effectual defence than if our bodies were covered with the hide of the rhinoceros.

The fuller the consideration which we give to this subject, the more convincing are the proofs that the painful sensibility of the skin is a benevolent provision, making us alive to those injuries, which, but for this quality of the nervous system, would bruise and destroy the internal and vital parts. In pursuing the inquiry, we learn with much interest that when the bones, joints, and all the membranes and ligaments which cover them, are exposed—they may be cut, pricked, or even burned, without the patient or the animal, suffering the slightest pain. These facts must appear to be conclusive; for who, witnessing these instances of insensibility, would not conclude that the parts were devoid of sensation. But when we take the true, philosophical, and I may say the religious view of the subject, and consider that pain is not an evil, but given for benevolent purposes and for some important object, we should be unwilling to terminate the investigation here.

In the first place, we must perceive that if a sensibility similar to that of the skin had been given to these internal parts, it must have remained unexercised. Had they been made sensible to pricking and burning, they would have possessed a quality which would never have been useful, since no such injuries can reach them; or never without warning being received through the sensibility of the skin.

But, further, if we find that sensibility to pain is a benevolent provision, and is bestowed for the purpose of warning us to avoid such violence as would affect the functions or uses of the parts, we may

yet inquire whether any injury can reach these internal parts without the sensibility of the skin being excited. Now, of this there can be no doubt, for they are subject to sprain, and rupture, and shocks, without the skin being implicated in the accident. If we have been correct in our inference, there should be a provision to guide us in the safe exercise of the limbs; and notwithstanding what has been apparently demonstrated of the insensibility of these internal parts, they must possess an appropriate sensibility, or it would imply an imperfection.

With these reflections, we recur to experiment—and we find that the parts, which are insensible to pricking, cutting, and burning, are actually sensible to concussion, to stretching, or laceration.

How consistent, then, and beautiful is the distribution of this quality of life! The sensibility to pain varies with the function of the part. The skin is endowed with sensibility to every possible injurious impression which may be made upon it. But had this kind and degree of sensibility been made universal, we should have been racked with pain in the common motions of the body: the mere weight of one part on another, or the motion of the joint, would have been attended with that degree of suffering which we experience in using or walking with an inflamed limb.

But on the other hand, had the deeper parts possessed no sensibility, we should have had no guide in our exertions. They have a sensibility limited to the kind of injury which it is possible may reach them, and which teaches us what we can do with impunity. If we leap from too great a height, or carry too great a burthen, or attempt to interrupt a body whose impetus is too great for us, we are warned of the danger as effectually by this internal sensibility, as we are of the approach of a sharp point or a hot iron to the skin.

Returning to the consideration of the sensibility of the skin, in order more fully to comprehend the benevolent effect of it, or in other words, its necessity to our very existence, I may be excused for stating the argument to the reader as I have delivered it in my lectures to the College of Surgeons.

"Without meaning to impute to you inattention or restlessness, I may request you to observe how every one occasionally changes his position and shifts the pressure of the weight of his body; were you constrained to retain one position during the whole hour, you would rise stiff and lame. The sensibility of the skin is here guiding you to that, which if neglected, would be followed even by the death of the part. When a patient has been received into the hospital with paralysis of the lower part of the body, we must give especial directions to the nurse and attendants that the position of his limbs should be changed at short intervals, that pillows should be placed under his loins and hams, and that they should be often shifted. If this be neglected, you know the consequence to be inflammation of the parts

that press upon the bed; from which come local irritation, then fever and mortification and death.

"Thus you perceive that the natural sensibility of the skin, without disturbing your train of thought, induces you to shift the body so as to permit the free circulation of the blood in the minute vessels; and that when this sensibility is wanting, the utmost attention of friends and the watchfulness of the nurse are but a poor substitute for this protection which nature is continually affording. If you suffer thus lying on a soft bed, when deprived of the sensibility of the skin, how could you encounter without it the rubs and impulses incident to an active life? You must now acknowledge that the sensibility of the skin is as much a protection to the frame generally, as the sensibility of the eyelids is to the eyes, and gives you a motive for gratitude which probably you never thought of."

The sensibility of the hand to heat, is a different endowment from that of touch. This sensibility to the varieties of temperature is seated in the skin, and is, consequently, limited to the exterior surface of the body. The internal parts of the body being of a uniform temperature, it would have been, in them, a quality altogether superfluous. But as we are surrounded by a temperature continually varying, and are subject to destruction by its extremes, and as we must suit our exertions or our contrivances so as to sustain life against these vicissitudes, our possession of this peculiar sensibility on the surface affords another proof of there having been a foreknowledge of our condition. We might, indeed, take our former example in evidence of what must befal through the want of this sensibility—the paralytic is brought to us severely burned, or with his extremities mortified through cold. A man having lost the sense of heat in his right hand, but retaining the muscular power, lifted the cover of a pan which had fallen into the fire and deliberately replaced it, not being conscious that it was burning hot; the effect, however, was the death and destruction of the skin of the palm and fingers. In this man there was a continual sensation of coldness in the affected arm, which actual cold applied to the extremity did not aggravate nor heat in any degree assuage.* Sensibility to heat is a safeguard in as much as it is capable of becoming a painful sensation, whilst it is a never-failing excitement to activity and a continual source of enjoyment.

And here we may remark an adaptation of the living property very different from the physical influence. Heat is uniform in its effect on matter; but the sensation varies as it is given or abstracted from the living body. Cold and heat are distinct sensations; and this is so far important that without such contrast we should not continue to enjoy the sense. For in the nervous system it holds

* There are certain morbid conditions of sensation when cold bodies feel intensely hot.—*Dr. Abercrombie's Inquiry into the Intellectual powers.*

universally that variety or contrast is necessary to sensation, the finest organ of sense losing its property by the continuance of the same impression. It is by a comparison of cold and heat that we enjoy either condition.

To contrast still more strongly the sensibility of the surface with the property of internal parts, to show how very different sensibility is, in reality, from what is suggested by first experience, and how admirably it is varied and accommodated to the functions, we shall add one other fact. The brain is insensible—that part of the brain, which if disturbed or diseased, takes away consciousness, is as insensible as the leather of our shoe! That the brain may be touched, or a portion of it cut off, without interrupting the patient in the sentence that he is uttering, is a surprising circumstance! From this fact Physiologists formerly inferred that the surgeon had not reached the more important organ of the brain. But that opinion arose from the notion prevailing that a nerve must necessarily be sensible. Whereas, when we consider that the different parts of the nervous system have totally distinct endowments, and that there are nerves, as I have elsewhere shown, insensible to touch and incapable of giving pain, though exquisitely alive to their proper office, we have no just reason to conclude that the brain should be sensible, or exhibit the property of a nerve of the skin. Reason on it as we may, the fact is so;—the brain, through which every impression must be conveyed before it is perceived, is itself insensible. This informs us that sensibility is not a necessary attendant on the delicate texture of a living part, but that it must have an appropriate organ, and that it is an especial provision.*

To satisfy my reader on this interesting subject, I shall take the contrast of two organs, one external and exposed, and the other internal and carefully excluded from injury.

The eye, consisting of its proper nerve of vision and its transparent humours and coats, is an organ of exquisite delicacy—not only is it exposed to all the injuries to which the general surface of the body is liable, but to be inflamed and rendered opaque by particles getting into it which are so light that they float in the atmosphere, and to the contact of which the common skin is quite insensible. The mechanical, and more obvious contrivance for the protection of this organ, is a ready motion of the eyelids and the shedding of tears; which coming, as it were, from a little fountain, play over the surface of the eye, and wash away whatever is offensive. But to the action of this little hydraulic and mechanical apparatus there is required an exquisite sensibility to direct it—not that kind of sensibility which enables the eye to receive the impressions of light—but a property more resembling the tenderness of the skin, yet happily adapted, by its fineness, to the condition of the organ.

* See the Sensibility of the Retina, Appendix.

A nerve, possessed of a quality totally different from that of the optic nerve, extends over all the exterior surfaces of the eye, and gives to those surfaces their delicate sensibility. Now it sometimes happens that this nerve is injured and its function lost; the consequences of which are very curious,—smoke and offensive particles, which are afloat in the atsmosphere, rest upon the eye: flies and dust lodge under the eyelids, without producing sensation, and without exciting either the hydraulic or the mechanical apparatus to act for the purpose of expelling them. But although they do not give pain, they nevertheless stimulate the surfaces so as to produce inflammation, and that causes opacity in the fine transparent membranes of the eye; and the organ is lost, although the proper nerve of vision remains entire. I have seen many instances of the eye being thus destroyed for want of sensibility to touch,* and it has been curious to remark that when the hand was waved or a feather brought near the eye, the person winked; yet he did not shut his eye on rubbing the finger across the eyeball, or when blood was removed by the lancet from the inflamed vessels. In those cases, when vision gave notice of danger to the organ, the patient winked to avoid it, but when the point touched the eye or eyelids, the sense of touch gave no alarm, and was followed by no action for the protection of the organ.

I shall present another instance of the peculiar nature of the sensibility which protects the eye. The Oculist has observed that by the touch of a thing as light as a feather, the muscles of the eye will be thrown into uncontrollable actions and spasm; but if the point of the finger be pressed somewhat rudely between the eyelids, and directly on the eye itself, he can by such means hold the eye steady for his intended operation, producing hardly any sensation, certainly no pain!

This is one of the little secrets of the art; the Oculist turns out the eyelids, and fingers the eye, in a manner which appears, at once, rude and masterly: and still the wonder grows that he can do such things with so much dexterity as to inflict no pain, when by daily experience we know that even a grain of sand in the eye will torture us. The explanation is this: the eye and eyelids are possessed of a sensibility which is so adjusted as to excite the action of its protecting parts against such small particles as might lodge and inflame its fine membranes. But the apparatus is not capable of protecting the surface of the eye against the intrusion of a stick or a stone; from such injuries it could not be defended by a delicate sensibility and involuntary action, but only by the effort of the will.

In these details we have new proofs of the minute relation which is established between the species of sensibility in an organ and the

* They are stated at length in my papers in the Philosophical Transactions, and in the Appendix of my work on the Nervous System.

end to be attained through it. It will not be denied that but for the pain to which the eye is exposed, we should quickly lose the enjoyment of the sense of vision altogether. But we were about to institute a comparison of the eye with the heart.

The observation of the admirable Harvey, the discoverer of the circulation of the blood, is to this effect. A noble youth of the family of Montgomery, from a fall and consequent abscess on the side of the chest, had the interior marvellously exposed, so that after his cure, on his return from his travels, the heart and lungs were still visible and could be handled; which when it was communicated to Charles I., he expressed a desire that Harvey should be permitted to see the youth and examine his heart. "When," says Harvey, "I had paid my respects to this young nobleman, and conveyed to him the king's request, he made no concealment, but exposed the left side of his breast, when I saw a cavity into which I could introduce my fingers and thumb; astonished with the novelty, again and again I explored the wound, and first marvelling at the extraordinary nature of the cure, I set about the examination of the heart. Taking it in one hand, and placing the finger of the other on the pulse of the wrist, I satisfied myself that it was indeed the heart which I grasped. I then brought him to the king that he might behold and touch so extraordinary a thing, and that he might perceive, as I did, that unless when we touched the outer skin, or when he saw our fingers in the cavity, this young nobleman knew not that we touched his heart!" Other observations confirm this great authority, and the heart is declared insensible. And yet the opinions of mankind must not be lightly condemned. Not only does every emotion of the mind affect the heart, but every change in the condition of the body is attended with a corresponding change in the heart: motion during health—the influence of disease—every passing thought will influence it. Here is the distinction manifested. The sensibility of the surface of the eye is for a purpose, and so is the sensibility of the heart. Whilst that of the eye guards it against injury from without, the heart, insensible to touch, is yet alive to every variation in the circulation, subject to change from every alteration of posture or of exertion, and is in sympathy of the strictest kind with the constitutional powers.

When we consider these facts, we can no longer doubt that the sensibilities of the living frame are appropriate endowments; not qualities necessarily arising from life; still less the consequences of delicacy of texture. Nor can we, I should hope, longer doubt that they are suited to the condition, and especially to the degree of exposure of each part, and for its protection. We perceive that the sensibilities vary in an extraordinary manner as they are given to external or to internal parts, as they belong to one apparatus of action or to another, and they are ever adapted to excite some salutary or necessary action. We perceive no instance of pain being be-

stowed as a source of suffering or punishment purely, or without finding it overbalanced by great and essential advantages—without, in short, being forced to admit that no happier contrivance could be found for the protection of the part. It is provided that the more an organ is exposed, and in proportion to its delicacy of organization—the more exquisitely contrived is the apparatus for its protection, and the more peremptory the call for the activity of that mechanism. The motive to action admits of no thought and no hesitation, and the action is more instantaneous than the quickest suggestion or impulse of the will.

We are speaking of the natural functions of the body. It requires a deeper consideration, and is indeed foreign to my subject to speak of the pains which result from disease, or to reconcile those who suffer in an extraordinary degree to the dispensations of Providence. But as a witness I may speak. It is my daily duty to visit certain wards of the hospital, where there is no patient admitted but with that complaint which most fills the imagination with the idea of insufferable pain and certain death. Yet these wards are not the least remarkable for the composure and cheerfulness of their inmates. The individual who suffers has a mysterious counterbalance to that condition, which to us who look upon her, appears to be attended with no alleviating circumstance.

It affords an instance of the boldness with which philosophers have questioned the ways of Providence, that they have asked—why were not all our actions performed at the suggestion of pleasure? why should we be subject to pain at all? In answer to this I should say, in the first place, that consistently with our condition, our sensations and pleasures, there must be variety in the impressions; such contrast and variety are common to every variety of sense; and the continuance of an impression on any one organ, occasions it to fade. If the eye continue to look steadfastly upon one object, the image is soon lost—if we continue to look on one colour, we become insensible to that colour, and opposite colours to each other are necessary for a perfect impression. So have we seen that in the insensibilities of the skin variations are necessary to continued sensation.

It is difficult to say what these philosophers would define as pleasure: but whatever exercise of the senses it should be, unless we are to suppose an entire change of our nature, its opposite is also implied. Nay, further, in this fanciful condition of existence, did any thing of our present nature prevail, emotions purely of pleasure would lead to indolence, relaxation, and indifference. To what end should there be an apparatus to protect the eye, since pleasure could never move us to its exercise? Could the windpipe and the interior of the lungs be protected by a pleasurable sensation attended with the slow determination of the will—instead of the rapid and powerful influence which the exquisite sensibility of the throat has upon the act of re-

spiration, or those forcible yet regulated exertions, which nothing but the instinctive apprehension of death could excite!

To suppose that we could be moved by the solicitations of pleasure and have no experience of pain, would be to place us where injuries would meet us at every step and in every motion, and whether felt or not, would be destructive to life. To suppose that we are to move and act without experience of resistance and of pain, is to suppose not only that man's nature is changed, but the whole of exterior nature also—there must be nothing to bruise the body or hurt the eye, nothing noxious to be drawn in with the breath: in short, it is to imagine altogether another state of existence, and the philosopher would be mortified were we to put this interpretation on his meaning. Pain is the necessary contrast to pleasure: it ushers us into existence or consciousness: it alone is capable of exciting the organs into activity: it is the companion and the guardian of human life.

CHAPTER VIII.

OF THE SENSES GENERALLY, INTRODUCTORY TO THE SENSE OF TOUCH.

Although we are most familiar with the sensibility of the skin, and believe that we perfectly understand the nature of the impressions upon it and the mode of their conveyance to the sensorium, yet there is a difficulty in comprehending the operations of all the organs of the senses—a difficulty not removed by the apparent simplicity of that of touch.

There was a time when the inquirer was satisfied on finding that in the ear there was a little drum and a bone to play upon it, with an accompanying nerve. This was deemed a sufficient explanation of the organ of hearing. It was thought equally satisfactory if in experimenting upon the eye, the image was seen painted at the bottom of it on the surface of the nerve. But although the impression be thus traced to the extremity of the nerve, still we comprehend nothing of the nature of that impression, or of the manner in which it is transmitted to the sensorium. To the most minute examination, the nerves, in all their course, and where they are expanded into the external organs of sense, seem the same in substance and in structure. The disturbance of the extremity of the nerve, the vibrations upon it, or the images painted upon its surface, cannot be transmitted to the brain according to any physical laws that we are acquainted with. The impression on the nerve can have no resemblance to the ideas suggested in the

mind. All that we can say is, that the agitations of the nerves of the outward senses are the signals, which the Author of nature has made the means of correspondence with the realities. There is no more resemblance between the impressions on the senses and the ideas excited by them, than there is between the sound and the conception raised in the mind of that man who, looking out on a dark and stormy sea, hears the report of cannon, which conveys to him the idea of despair and shipwreck—or between the impression of light on the eye, and the idea of him who, having been long in terror of national convulsion, sees afar off a column of flame, which is the signal of actual revolt.

By such illustrations, however, we rather show the mind's independence of the organ of sense, and how a tumult of ideas will be excited by an impression on the retina, which, notwithstanding, may be no more intense than that produced by a burning taper. They are instances of excited imagination. But even the determined relations which are established in a common act of perception between the sensation and the idea in the mind, have no more actual resemblance. How the consent, which is so precise and constant, is established, can neither be explained by anatomy nor by physiology, nor by any mode of physical inquiry whatever.

From this law of our nature, that certain ideas originate in the mind in consequence of the operation of corresponding nerves, it follows—that one organ of sense can never become the substitute for another, so as to excite in the mind the same idea.

When an individual is deprived of the organs of sight, no power of attention, or continued effort of the will, or exercise of the other senses, can make him enjoy the class of sensations which is lost. The sense of touch may be increased in an exquisite degree; but were it true, as has been asserted, that individuals can discover colours by the touch, it could only be by feeling a change upon the surface of the stuff and not by any perception of the colour. It has been my painful duty to attend on persons who have pretended blindness and that they could see with their fingers. But I have ever found that by a deviation from truth in the first instance, they have been entangled in a tissue of deceit; and have at last been forced into admissions which demonstrated their folly and weak inventions. I have had pity for such patients, when they have been the subjects of nervous disorders which have produced extraordinary sensibility in their organs—such as a power of hearing much beyond our common experience; for it has attracted high interest and admiration, and has gradually led them to pretend to powers greater than they actually possessed. In such cases it is difficult to distinguish the symptoms of disease, from the pretended gifts which are boasted of.

Experiment proves, what is suggested by Anatomy, that not only the organs are appropriated to particular classes of sensations,

but that the nerves, intermediate between the brain and the outward organs, are respectively capable of receiving no other sensations but such as are adapted to their particular organs.

Every impression on the nerve of the eye, or of the ear, or on the nerve of smelling, or of taste, excites only ideas of vision, of hearing, of smelling, or of tasting; not solely because the extremities of the nerves, individually, are suited to external impressions, but because the nerves are, through their whole course and wherever they are irritated, capable of exciting in the mind the idea to which they are appropriate, and no other. A blow, an impulse quite unlike that for which the organs of the senses are provided, will excite them all in their several ways: the eyes will flash fire, while there is noise in the ears. An officer received a musket-ball which went through the bones of his face—in describing his sensations, he said that he felt as if there had been a flash of lightning, accompanied with a sound like the shutting of the door of St. Pauls.

On this circumstance, of every nerve being appropriated to its function, depend the false sensations which accompany the morbid irritation of them from internal causes, when there is in reality nothing presented externally;—such as flashes of light, ringing of the ears, and bitter taste or offensive smells. These sensations are caused, through the excitement of the respective nerves of sense, by derangement of some internal organ, and most frequently of the stomach.

But my chief object is to show that the most perfect proof of power and of design, is to be found in this, that the perceptions or ideas arising in the mind, are in correspondence with the qualities of external matter; and that, although the manner in which the object presented to the outward sense and the idea of it are connected, must ever be beyond our comprehension, they are, notwithstanding, indissolubly united; and when the object is so presented to us, it is attended with the conviction of its real existence—a conviction independent of reason and to be regarded as a first law of our nature.

The doctrine of vibrations acting on the nerve of vision, has had powerful advocates in our day. But it is quite at variance with anatomy, and assumes more than is usually granted to hypotheses. It requires that we shall imagine the existence of an ether: and that this fluid shall have laws unlike anything of which we have experience. It supposes a nervous fluid and tubes of fibres in the nerve, to receive and convey these vibrations. It supposes everywhere *motion* as the sole means of propagating sensation.

These opinions have been formed on the misconception that if a certain kind or degree of vibration be communicated to any nerve, this particular motion must be propagated to the sensorium, and a corresponding idea excited in the mind. For example, it is con-

ceived that if the nerve of hearing were placed in the bottom of the eye, it would be impressed with the vibration proper to light, and that this being conveyed to the brain, the sensation of light or colours would result—All which is contrary to fact.

Nor can I be satisfied that light and colours shall result from vibrations which shall vary "from four hundred and fifty-eight millions of millions to seven hundred and twenty-seven millions of millions in a second," when I find that a fine needle pricking the retina will produce brilliant light, and that the pressure of the finger on the ball of the eye will gve rise to all the colours of the rainbow!

There is a condition of the percipient or sentient principle, of the brain and nerves, as well as of the organ of sense, conforming to the impression to be made: a condition which corresponds with the qualities of matter. The several organs of sense may be compared to so many instruments, which the philosopher applies to distinguish the several qualities of the body which he investigates. The different properties of that body are not communicable through any one instrument; and so in the use of the senses, each organ is provided for receiving a particular influence, and no other.

However mortifying it may be to acknowledge ignorance, variation of motion in a body cannot be admitted as the cause of sensation universally; nor, as I said, can we comprehend anything of the manner in which the nerves are affected; certainly we know nothing of the manner in which sensation is propagated or the mind ultimately influenced. But there is a very pleasing view of the subject, notwithstanding; which is to observe the correspondence of the mind (through a series of organic parts) with the external world, or with the condition and qualities of matter: than which nothing can convey a more sublime idea of Power, and of the system or unity of organic and inorganic creations.

Returning to the consideration of the sensibility of the skin and the sense of touch, this property is as distinct an endowment as that which belongs to the eye. It is neither inferior nor more common. It is not consequent upon the mere exposure of the delicate surface of the animal body. It is a distinct sense, the organ of which is seated in the skin; and it is necessary that this organ of sense should be extended widely over the surface of the body. Yet the nerves are as appropriate and distinct as if they were gathered into one trunk, such as we find them to be in the organs of vision and hearing.

Although the portion of nervous matter on which the sensation and perception of touch depend, be necessarily extended in its sentient extremities over the whole exterior surface of the body, it is very much concentrated towards the brain: and it is there appropriated, in the same manner as the nerves of vision and of hearing, to its peculiar function of raising corresponding perceptions in the mind.

Perhaps this will be better understood from the fact—that a certain large portion of the skin may be the seat of excruciating pain, and yet the surface, which to the patient's perception is the seat of that pain, will be altogether insensible to cutting, burning, or any mode of destruction! "I have no feeling in all the side of my face, and it is dead; yet surely it cannot be dead, since there is a constant pricking pain in it." Such were the words of a young woman whose disease was at the root of the nerve of sensibility near the brain.* The disease destroyed the function of this nerve of the head, as to its property of conveying sensation from the exterior: and substituted that morbid impression on the trunk which was referred to the tactile extremities.

If we use the term common sensibility, we can do so only in reference of touch, as it is the sense that is most necessary to animal existence, and as it is enjoyed by all animals from the lowest to the highest in the chain of existence.

While this sense is distinct from the others, it is the most important of all; since through it alone some animals possess the consciousness of existence; and to those that enjoy many organs of sense, that of touch, as we shall presently show, is necessary to the full developement of the powers of all the other organs.

OF THE ORGAN OF TOUCH.

Touch is that peculiar sensibility which gives the consciousness of the resistance of external matter, and makes us acquainted with the hardness, smoothness, roughness, size, and form of bodies. It enables us to distinguish what is external from what belongs to us; and while it informs us of the geometrical qualities of bodies, we must refer to this sense also our judgment of distance, of motion, of number, and of time.

Presuming that the sense of touch is exercised by means of a complex apparatus—by a combination of the consciousness of the action of the muscles with the sensibility of the proper nerves of touch, we shall, in the first place, examine in what respect the organization resembles that of the other senses.

We have said before that, on the most minute examination of the extremity of a nerve, no appropriate structure can be detected; and that the nerves expanded on the organs of sense appear every where the same,—soft, pulpy, prepared for impression, and so distributed that the impression shall reach them. What is termed the structure of the organs of sense, is that apparatus by which the external impression is conveyed inwards, and by which its force is concentrated on the extremity of the nerve. The mechanism by which those external organs are suited to their offices, is highly interesting; it serves

* See Papers by the author in the Philosophical Transactions.

to show (in a way that is level to our comprehension, as most resembling things of human contrivance) the design with which the fabric is constructed. Thus, the eye is so seated and so formed as to embrace the greatest possible field of vision. We can understand the happy effects of the convexity of the transparent cornea, the influence of three humours of various densities acting like an achromatic telescope; we can admire the precision with which the rays of light are concentrated on the retina, and the beautiful provision for enlarging or diminishing the pencil of light, in proportion to its intensity: but all this explains nothing, in respect to the perception that is excited in the mind by the impulse on the extremity of the nerve.

In like manner, in the complex apparatus of the ear, we see how this organ is formed with reference to a double course of impressions, as they come through the solids or through the body, and as they come through the atmosphere. We comprehend how the undulations and vibrations of the air are collected and concentrated; how they are directed, through the intricate passages of the bone, to a fluid in which the nerve of hearing is suspended; and we see how, at last, that nerve is moved. But we can comprehend nothing more from the study of the external organ of hearing.

The illustration is equally clear in reference to the organ of smelling, or of taste. There is nothing in the nerve itself, either of the nose or of the tongue, which can explain why it is susceptible of the particular impression. For these reasons, we are prepared to expect very little complexity in the organ of touch, and to believe that the peculiarity of the sense consists more in the property bestowed on the nerve, than in the mechanical adaptation of the exterior organ.

OF THE CUTICLE.

The cuticle or epidermis covers the true skin, excludes the air, limits the perspiration, and in some degree regulates the heat of the body. It is a dead or insensible covering; it guards from contact the true vascular surface of the skin; and in this manner, it often prevents the communication of infection. We are most familiar with it as that scarf skin which scales off after fevers, or by the use of the flesh-brush, or by the friction of the clothes; for it is continually separating in thin scales, whilst it is as regularly formed anew by the vascular surface below. The condition of this covering is intimately connected with the organ of touch. The habit of considering things as produced accidentally, has induced some anatomists to believe that the cuticle is formed by the hardening of the true skin. The fact, however, that the cuticle is perfect in the new-born infant, and that even then it is thickest on the hands and feet, should have shown that, like everything in the animal structure, it participates in the great design.

The cuticle is the organ of touch in this respect, that it is the medium through which the external impression is conveyed to the nerves of touch; and the manner in which this is accomplished is not without interest. The extremities of the fingers exhibit all the provisions for the exercise of this sense. The nails give support to the fingers; they are formed broad and shield-like,* in order to sustain the elastic cushion which forms their extremity; and the fulness and elasticity of the ends of the fingers adapt them admirably for touch. But on a nearer inspection, we see a more particular provision in the points of the fingers. Wherever the sense of feeling is most exquisite, there are minute spiral ridges of cuticle. These ridges have, corresponding with them, depressed lines on the inner surface of the cuticle; and these again give lodgement to a soft pulpy matter, in which lie the extremities of the sentient nerves. There the nerves are sufficiently protected, while they are exposed to impressions through the elastic cuticle, and thus give the sense of touch.—The organization is simple, yet it is in strict analogy with the other organs of sense.

Every one must have observed a tendency in the cuticle to become thickened and stronger by pressure and friction. If the pressure be partial and severe, the action of the true skin is too much excited, fluid is thrown out, and the cuticle is raised in a blister. If it be still partial, but more gradually applied, a corn is formed. If, however, the general surface of the palms or soles be exposed to pressure, the cuticle thickens, until it becomes a defence like a glove or a shoe. Now, what is most to be admired in this thickening of the cuticle is, that the sense of touch is not lost, or indeed diminished, certainly not at all in proportion to the protection afforded by the thickened skin.

The thickened cuticle partakes of the structure of the hoofs of animals: and we shall now attend to the nature of the hoof, as the best possible illustration of the manner in which the sensibility of the skin is in a due degree preserved whilst the surface is guarded.

The human nail is a continuation of the cuticle, and the hoof of an animal belongs to the same class of parts. In observing the manner in which the nerves enter the hoof, we have, in fact, a magnified view of that which exists, but is only more minute and delicate, in the fingers. We may take the horse's foot as the example.—When the crust or hoof, which is insensible, is separated from the living part, we see small villi hanging from the vascular surface, and which have been withdrawn from the crust; looking to the inside of the crust, we perceive the pores from which these villi have been pulled. These processes of the living surface are not merely extremities of nerves; they consist of the nerves and the necessary accompaniments of membrane and blood-vessels, on a very minute

* *Unguis scutiformis.*

scale. For it must be remembered that nerves can perform no function unless supplied with blood, all qualities of life being supported through the circulating blood. These nerves, so prolonged into the hoof, receive the vibrations of that body. By this means the horse is sensible to the motion and pressure of its foot, or to its percussion against the ground; and without this provision, there would be a certain imperfection in the limb.

In a former part of this treatise I have shown by what curious mechanism the horse's foot is made yielding and elastic, for the purpose of bearing the percussion against the ground. But in made roads, and with the imperfections of shoeing, the pressure and concussion are too severe and too incessant; so that the protecting sensibility of the foot is converted into a source of pain from the inflammation which arises, and the horse is thus "foundered." There is a remedy for this condition in dividing the nerve; the consequence of which operation is, that the horse, instead of moving with timid steps, puts out his feet freely, and the lameness is cured. If, however, we were to receive the statement thus barely, the fact would militate against our conclusion that mechanical provision and sensibility go together, being equally necessary to the perfection of the instrument. We must take into consideration this leading fact, that pressure against the sole and crust is necessary to the play of the foot and to its perfection. When this part becomes inflamed, the animal does not put its foot freely down, nor does it bear its weight upon the hoof so as to bring all the parts into action; hence contraction is produced, the most common defect of the horse's hoof. When the animal is relieved from pain by the division of the nerve, it uses the foot freely, and use restores all the natural actions of this fine piece of mechanism. It is obvious, however, that there is a certain defect; the horse has lost his natural protection, and must now be indebted to the care of his rider. It has not only lost the pain which should guard against over exertion, but the feeling of the ground, which is necessary to his being perfectly safe as a roadster.

The teeth are provided with sensibility much in the same manner as the hoof of the horse is; for although the bone and enamel have no sensibility, yet a branch of a sensible nerve (the fifth) enters into the cavity of every tooth, and the vibration being communicated through the tooth to the nerve, the smallest grain is felt between the teeth.

But, to return to the human hand; in the fingers and palm of a man who uses the fore-hammer, the cuticle is thickened in a remarkable manner; the lines, however, become deeper, and the villi longer; which, joined to the aptitude of the cuticle to convey the impression to those included nerves, leaves him in possession of the sense of touch in a very high degree.

In the foot of the ostrich we may have a magnified view of the thickened cuticle and the lengthened nerves. The outer skin almost

equals in thickness the hoof of the *solidungula*, and when it is separated from the sensible sole, the villi, or papillæ, having in them the sensible nerves, are withdrawn, leaving corresponding foramina or pores in the sole. We perceive that if the object had been merely to cover and protect the foot, it would have been sufficient to have invested it with a succession of solid and dead layers of cuticle. This would have been the case had the cuticle been merely thickened by pressure, and had there been no design to make a provision adapted in all respects to the habits of the bird.

Such, then, is the structure of the organ of touch: obvious in the extremities of the fingers; magnified in the foot of the horse or of the ostrich; and existing even in the delicate skin of the lips.

I have casually noticed that increased vascularity is always an accompaniment of nerves, and necessary to the sensibility of a part. In the museum of the College of Surgeons we see that Mr. Hunter had taken the pains to demonstrate this, by the injection of the blood-vessels of a slug. Although fluid was injected from its heart, the blush from the vermilion extends over its foot; the foot, in these gasteropoda, being the whole lower flat surface on which the animal creeps. This surface is also the organ of touch, by which it feels and directs its motions. It is on the same principle, if we may compare such things, that we explain the rosy-tipped fingers and the ruby lips, which imply fine sensibility combined with high vascularity.

Having described the relation of the cuticle to the nerves of touch, we may take notice of another quality, in its roughness, and of the advantages accruing from this. In the first place, as to the subserviency of this quality to feeling, we must be sensible that in touching a finely polished surface the organ is but imperfectly exercised, as compared with its condition when we touch or grasp a rough and irregular body. Had the cuticle been finely polished on its surface it would have been but ill suited to touch: but, on the contrary, it has a very peculiar roughness which adapts it to feeling. A provision for friction, as opposed to smoothness, is a necessary quality of some parts of the skin. The roughness of the cuticle has the advantage of giving us a firmer grasp, and a steadier footing. Nothing is so little apt to slip as the thickened cuticle of the hand or foot. In the hoofs of animals, as might be expected, this structure is further developed. The chamois or goat steps securely on the ledges of rocks and at great heights, where it would seem impossible to cling. On the pads or cushions of the cat, the cuticle is rough and granular; and in the foot of the squirrel, indeed of all animals which climb, those pads covered with the peculiar texture of the cuticle, give security in descending, as their claws enable them to climb.

In concluding this section, we perceive that the organ of touch consists of nerves appropriated to receive the impressions of bodies capable of affording resistance. Fine filaments of those nerves, wrapt up in delicate membrane with their accompanying arteries

and veins, project from the true skin into corresponding grooves or foramina of the cuticle. They are not absolutely in contact with the cuticle, but are surrounded with a semi-fluid matter. By this fluid and by the cuticle they are protected, at the same time that they are sensible to the pressure made on the surface, and to cutting, pricking, and heat.* But this capacity, we repeat, is not owing, strictly speaking, to anything in the structure of the organ, but to the appropriation of the nerves to this class of sensations.

CHAPTER IX.

OF THE MUSCULAR SENSE.

OF THE SENSIBILITY OF THE INFANT TO IMPRESSIONS, AND THE GRADUAL IMPROVEMENT OF THE SENSE OF TOUCH.

A notion prevails that the young of animals are directed by instinct, but that there is an exception in regard to the human offspring: that in the child we have to trace the gradual dawn and progressive improvement of reason. This is not quite true; we doubt whether the body would ever be exercised under the influence of reason alone, and if it were not first directed by sensibility which are innate or instinctive.

The sensibilities and the motions of the lips and tongue are perfect from the beginning: and the dread of falling is shown in the young infant long before it can have had experience of violence of any kind.

The hand, which is to become the instrument for perfecting the other senses and developing the endowments of the mind itself, is in the infant absolutely powerless. Pain is poetically described as that power into whose "iron grasp" we are consigned, to be introduced to a material world; now, although the infant is capable of an expression of pain, which cannot be misunderstood and is the same which accompanies all painful impressions during the whole life, yet it is unconscious of the part of the body which suffers. We have again recourse to the surgeon's experience. There occur certain

* It is a curious confirmation of the fact, that the cutaneous nerve is adapted to receive impressions from the varieties of temperature, that when disease takes place in the centre of the trunk of a nerve, or when the nerve is surrounded with diseased parts, the sensation of burning accompanies the pain; and the patient refers this to the part of the skin to which the extreme branch of the nerve is distributed. By a burning sensation in the sole of the foot, I have been directed to the disease seated in the centre of the thigh.

congenital imperfections which require an operation at this early stage of life; but the infant makes no direct effort with its hand to repel the instrument, or to disturb the dressing, as it will at a period somewhat later.

The lips and tongue are first exercised; the next motion is to put the hand to the mouth, in order to suck it: and no sooner are the fingers capable of grasping, than whatever they hold is carried to the mouth. So that the sensibility to touch in the lips and tongue, and their motions, are the first inlets to knowledge; and the use of the hand is a later acquirement.

The knowledge of external bodies as distinguished from ourselves, cannot be acquired until the organs of touch in the hand have become familiar with our own limbs; we cannot be supposed capable of exploring anything by the motion of the hand, or of judging of the form or tangible qualities of an object pressed against the skin, before we have a knowledge of our own body as distinguished from things external to us.

The first office of the hand, then, is to exercise the sensibility of the mouth: and the infant as certainly questions the reality of things by that test, as the dog does by its acute sense of smelling. In the infant, the sense of the lips and tongue is resigned only in favour of the sense of vision, when that sense has improved and offers a greater gratification, and a better means of judging of the qualities of bodies. The hand very slowly acquires the sense of touch, and many ineffectual efforts are seen in the arms and fingers of the child before the direction of objects or their distance is ascertained. Gradually the length of the arm, and the extent of its motions become the measure of distance, of form, of relation, and perhaps of time.

Next in importance to the sensibility of the mouth, we may contemplate that sense which is early exhibited in the infant,—the terror of falling. The nurse will tell us that the infant lies composed while she carries it in her arms up stairs; but that it is agitated in carrying it down. If an infant be laid upon the arms and dandled up and down, its body and limbs will be at rest whilst it is raised; but they will struggle and make an effort as it descends. There is here the indication of a sense, an innate feeling of danger, the influence of which we may perceive when the child first attempts to stand or run. When the child is set upon its feet, and the nurse's arms form a hoop around it without touching it, it slowly learns to balance itself and stand; but under a considerable apprehension. Presently, it will stand at such a distance from the nurse's knee, that if it should lose its balance, it can throw itself for protection into her lap. In these its first attempts to use its muscular frame, it is directed by an apprehension which cannot as yet be attributed to experience. By degrees it acquires the knowledge of the measure of its arm, the relative distance to which it can reach, and the power of its muscles. Children, therefore, are cowardly by instinct: they show an appre-

hension of falling; and we may gradually trace the efforts which they make, under the guidance of this sensibility, to perfect the muscular sense. In the mean time, we perceive how instinct and reason are combined in early infancy: how necessary the first is to existence; how it is subservient to reason: and how it yields to the progress of reason, until it becomes so obscured that we can hardly discern its influence.

When treating of the senses, and showing how one organ profits by the exercise of the other, and how each is indebted to that of touch, I was led to observe that the sensibility of the skin is the most dependent of all on the exercise of another quality. Without a sense of muscular action or a consciousness of the degree of effort made, the proper sense of touch could hardly be an inlet to knowledge at all. I am now to show that the motion of the hand and fingers, and the sense or consciousness of their action, must be combined with the sense of touch, properly so called, before we can ascribe to it the influence which it possesses over the other organs.

In my general course of lectures on anatomy, I ventured on this explanation from the commencement; much doubting, however, the correctness of my reasoning, from seeing that the great authorities on this subject made no account of the knowledge derived from the motions of our own frame. I called this consciousness of muscular exertion a sixth sense, considering it as essential to the exercise of the sense of touch. I can now refer, in confirmation of this view, to the works of philosophers who have been educated to medicine; and to whom the necessity of the combination of the two faculties had suggested itself as it had to me.* Those distinctions were connected with my inquiries into the functions of the nervous system, and in some measure directed them.†

* See Dr. Brown's Lectures on Moral Philosophy.

† It was this conviction—that we are sensible of the action of the muscles, which led me to the investigation of their nerves; first, by anatomy, and then by experiment. I was finally enabled to show that the muscles had two classes of nerves—that on exciting one of these, the muscle contracted; that on exciting the other, no action took place. The nerve which had no power was found to be a nerve of sensation: and thus, it was proved that there is a nervous circle connecting the muscles with the brain: that one nerve is not capable of transmitting what is called the nervous spirits, in two different directions at one instant of time; but that for the regulation of the muscles, there is a nerve of sensibility to convey the nervous influence from the muscles towards the sensorium, as well as a nerve of action for conveying the mandate of the will to the muscles. In their distribution through the body, the nerves which possess these two distinct powers are wrapped up, or, as it were, woven together in the same sheath; and they present to the eye the appearance of one nerve. It was only by examining the nerves at their roots, that is, where they arise from different tracts of the brain and spinal marrow, and before they have coalesced, that I succeeded in demonstrating their distinct functions. In the face, the nerve of motion passes by a circuitous course, apart from the nerve of sensation, to be distributed in the muscles; and therefore the distinct characters of these nerves were more easily proved by experiment than in any other part of the body. See the Philosophical Transactions on the "Nervous Circle which connects the Voluntary Muscles with the Brain," and the "Nervous System." 4to. Longman.

The Abbé Nollet, after extolling the sense of touch as superior to all the other senses, and as deserving to be considered the *genus* under which the others should be included as subordinate *species*, makes this remark—"Besides, it has this advantage over them, to be at the same time both active and passive; for it not only puts it in our power to judge of what makes an impression upon us, but likewise of what resists our impulsions." The mistake here lies in giving to the nerves of touch a property which must belong to the actions of muscles. So it is affirmed by physiologists, as I have already had occasion to state, that the sense of touch differs from the other senses by this circumstance—that an effort is propagated towards it, as well as a sensation received from it. This confusion obviously arises from considering the muscular agency, which is directed by the will during the exercise of touch, as belonging to the nerve of touch properly. We proceed to show how the sense of motion and that of touch are necessarily combined.

When a blind man, or a man with his eyes shut, stands upright, neither leaning upon, nor touching aught; by what means is it that he maintains the erect position? The symmetry of his body is not the cause; the statue of the finest proportion must be soldered to its pedestal, or the wind will cast it down. How is it, then, that a man sustains the perpendicular posture, or inclines in due degree towards the winds that blow upon him! It is obvious that he has a sense by which he knows the inclination of his body, and that he has a ready aptitude to adjust it, and to correct any deviation from the perpendicular. What sense then is this? for he touches nothing, and sees nothing; there is no organ of sense hitherto observed which can serve him, or in any degree aid him. Is it not that sense which is exhibited so early in the infant, in the fear of falling? Is it not the full developement of that property which was early shown in the struggle of the infant while it yet lay in the nurse's arms? It can only be by the adjustment of muscles that the limbs are stiffened, the body firmly balanced and kept erect. There is no other source of knowledge, but a sense of the degree of exertion in in his muscular frame, by which a man can know the position of his body and limbs, while he has no point of vision to direct his efforts, or the contact of any external body. In truth, we stand by so fine an exercise of this power, and the muscles are, from habit, directed with so much precision and with an effort so slight, that we do not know how we stand. But if we attempt to walk on a narrow ledge, or stand in a situation where we are in danger of falling, or rest on one foot, we become then subject to apprehension: the actions of the muscles are, as it were, magnified and demonstrative of the degree in which they are excited.

We are sensible of the position of our limbs; we know that the arms hang by the sides; or that they are raised and held out; although we touch nothing and see nothing. It must be a property

internal to the frame by which we know this position of the members of our body: and what can this be but a consciousness of the degree of action and the adjustment of the muscles? At one time, I entertained a doubt whether this proceeded from a knowledge of the condition of the muscles or from a consciousness of the degree of effort which was directed to them in volition. It was with a view to elucidate this, that I made the observations which terminated in the discovery that every muscle had two nerves—one for sensation, and one to convey the mandate of the will and direct its action. I had reasoned in this manner—we awake with a knowledge of the position of our limbs: this cannot be from a recollection of the action which placed them where they are; it must, therefore, be a consciousness of their present condition. When a person in these circumstances moves, he has a determined object; and he must be conscious of a previous condition before he can desire a change or direct a movement.

After a limb has been removed by the surgeon, the person still feels pain, and heat, and cold in it. Urging a patient to remove who has lost his limb, I have seen him catch at the limb to guard it, forgetful that it was removed; and long after his loss, he experiences a sensation not only as if the limb remained, but as if it were placed or hanging in a particular position or posture. I have asked a patient —"Where do you feel your arm now?" and he has said, "I feel it as if it lay across my breast," or that it is "lying by my side." It seems also to change with the change of posture of the body. These are additional proofs of a muscular sense; that there is an internal sensibility corresponding with the changing condition of the muscles; and that as the sensations of an organ of sense remain after the destruction of the outward organ, so here a deceptious sensibility to the condition of the muscles, as well as to the condition of the skin, is felt after the removal of the limb.

By such arguments I have been in the habit of showing that we possess a muscular sense, and that without it we could have no guidance of the frame. We could not command our muscles in standing, far less in walking, leaping, or running, had we not a perception of the condition of the muscles previous to the exercise of the will. And as for the hand, it is not more the freedom of its action which constitutes its perfection, than the knowledge which we have of these motions, and our consequent ability to direct it with the utmost precision.

The necessity for the combination of two distinct properties of the nervous system in the sense of touch becomes more obvious if we examine their operation in another but analogous organ; for example, in the palpa or tentacula of the lower animals. These animals use those instruments to grope their way: and they consist of a rigid tube containing a pulpy matter, in which there is a branch of nerve that possesses in an exquisite degree the sense of touch.

Now when this instrument touches a body and the vibration runs along the pulp of the nerve, the animal can be sensible only of an obstruction; but where is that obstruction, and how is the creature's progress to be directed to avoid it? We must acknowledge that the instrument moves about and feels on all sides, and that it is the action of the muscles moving this projecting instrument, and the sense of their activity, which convey the knowledge of the place or direction of the obstructing body. It appears, therefore, that even in the very lowest creatures the sense of touch implies the comparison of two distinct senses.

That insects have the most exquisite organs of sense must be allowed: but we do not reflect on the extraordinary accuracy with which they measure distance; which is an adaptation of the muscular exertion to the sense of vision. The spider which I have already alluded to in a former chapter—the *aranea scenica*, when about to leap, elevates itself upon its fore legs, and lifting its head, seems to survey the spot before it jumps. When this insect spies a small gnat or fly upon the wall, it creeps very gently towards it, with short steps, till it comes within a proper distance, and then it springs suddenly like a tiger. It will jump two feet to seize upon a bee.*

We have a more curious instance of the precision of eye and the adaptation of muscular action in the *chætodon rostratus*.† This fish inhabits the Indian rivers, and lives on the smaller aquatic flies. When it observes a fly alighted on a twig or flying near (for it can shoot them on the wing) it darts a drop of water with so steady an aim as to bring the fly down into the water, when it falls an easy prey. These fishes are kept in large vases for amusement, and if a fly be presented on the end of a twig, they will shoot at it with surprising accuracy. In its natural state it will hit a fly at the distance of from three to six feet. The *zeus insidiator*‡ has also the power of forming its mouth into a tube and squirting at flies so as to encumber their wings and bring them to the surface of the water. Whether led to admire the wonderful power of instinct in these inferior creatures, or the property acquired by our own eye, we must acknowledge a compound operation.§

The impression of odours on the nerve of smelling is exactly what some would have us to believe the effect of light is on the nerve of vision; and yet, that impression on the nerve of vision is sufficient, in their opinion, to inform us of all that we know through the eye. Now of the direction and distance from which odours come, we are quite ignorant, until by turning the head and directing

* Kirby. † Chœtodon, a genus of the Acanthopterygii.

‡ Belonging to another genus of the same order.

§ In these instances a difficulty will readily occur to the reader; how does the fish judge of position, since the rays of light are refracted at the surface of the water? Does instinct enable it to do this, or is it by experience?

the nostrils, and moving this way and that, we make comparison, and discover on which side the smell is strongest on the sense. We can judge of the direction of sounds without turning the head, because the strength of vibration is unequal on the two sides of the head, and a comparison is made of the two impressions. But when a person is deaf of one ear the operation is difficult; he is often mistaken as to the direction of sounds, and he has more necessity to turn the head and to compare the position of the tube of the ear with the strength of the impressions. Accordingly, in mixed company, where there are many speakers, he appears positively deaf, from the impossibility of distinguishing minutely the direction of sounds.

The last proof of the necessity of the combination of the muscular sense with the sense of contact will be conclusive. The following is not a solitary instance:—

A mother while nursing her infant was seized with a paralysis, attended by the loss of power on one side of her body, and the loss of sensibility on the other side. The surprising, and, indeed, the alarming circumstance here was, that she could hold her child to her bosom with the arm which possessed muscular power, but only as long as she looked at the infant. If surrounding objects withdrew her attention from the state of her arm, the flexor muscles gradually relaxed and the child was in danger of falling. The details of the case do not belong to our present inquiry; but we see here, first, that there are two properties in the arm; which is shown by the loss of the one and the continuance of the other; secondly, that these properties exist through different conditions of the nervous system; and, thirdly, we perceive how ineffectual to the exercise of the limbs is the continuance of the muscular power, without the sensibility which should accompany and direct it.

The property in the hand of ascertaining the distance, the size, the weight, the form, the hardness and softness, the roughness or smoothness of objects results from the combined perception—through the sensibility of the proper organ of touch and the motion of the arm, hand, and fingers. But the motion of the fingers is especially necessary to the sense of touch; they bend, extend, or expand, moving in all directions like palpa, with the advantage of embracing the object, and feeling it on all its surfaces; sensible to its solidity and to its resistance when grasped; moving round it and gliding over its surface, and, therefore, feeling every asperity.

THE PLEASURES ARISING FROM THE MUSCULAR SENSE.

The exercise of the muscular frame is the source of much of the knowledge which is usually supposed to be obtained through the organs of sense; and to this source, also, we must trace some of our chief enjoyments. We may, indeed, affirm that it is benevolently

provided that vigorous circulation, and, therefore, the healthful condition both of the mind and the body, shall result from muscular exertion and the alternation of activity and repose.

The pleasure which arises from the activity of the body is also attended by gratification from the exercise of a species of power—as in mere dexterity, successful pursuit in the field, or the accomplishment of some work of art. This activity is followed by weariness and a desire for rest, and although unattended with any describable pleasure or local sensation, there is diffused through every part of the frame, after fatigue and whilst the active powers are sinking into repose, a feeling almost voluptuous. To this succeeds the impatience of rest, and thus we are urged to the alternations which are necessary to health, and invited on from stage to stage of our existence.

We owe other enjoyments to the muscular sense. It would appear that in modern times we know comparatively little of the pleasures arising from motion. The Greeks, and even the Romans, studied elegance of attitude and movement. Their apparel admitted of it, and their exercises and games must have led to it. Their dances were not the result of mere exuberance of spirits and activity; they studied harmony in the motion of the body and limbs, and majesty of gait. Their dances consisted more of the unfolding of the arms than of the play of their feet,—"Their arms sublime that floated on the air." The Pyrrhic dances were elegant movements, joined to the attitudes of combat, and performed in correct coincidence with the expression of the music. The spectators in their theatres must have had very different associations from ours, to account for the national enthusiasm arising from music and their rage excited by a mere error in the time.

This reminds us that the divisions in music in some degree belong to the muscular sense. A man will put down his staff in regulated time, and the sound of his steps will fall into a measure, in his common walk. A boy striking the railing in mere wantonness, will do it with a regular succession of blows. This disposition of the muscular frame to put itself into motion with an accordance to time is the source of much that is pleasing in music, and aids the effect of melody. There is thus established the closest connexion between the enjoyments of the sense of hearing and the exercise of the muscular sense.*

* To learn how much the enjoyment of the sense of vision belongs to motion, see the "Additional Illustrations," at the end of the volume.

CHAPTER X.

THE HAND NOT THE SOURCE OF INGENUITY OR CONTRIVANCE, NOR CONSEQUENTLY OF MAN'S SUPERIORITY.

Seeing the perfection of the hand, we can hardly be surprised that some philosophers should have entertained the opinion with Anaxagoras, that the superiority of man is owing to his hand. We have seen that the system of bones, muscles, and nerves of this extremity is suited to every form and condition of vertebrated animals; and we must confess that it is in the human hand that we have the consummation of all perfection as an instrument. This, we perceive, consists in its power, which is a combination of strength with variety and extent of motion; we see it in the forms, relations and sensibility of the fingers and thumb; in the provisions for holding, pulling, spinning, weaving, and constructing; properties which may be found in other animals, but which are combined to form this more perfect instrument.

In these provisions the instrument corresponds with the superior mental capacities, the hand being capable of executing whatever man's ingenuity suggests. Nevertheless, the possession of the ready instrument is not the cause of the superiority of man, nor is its aptness the measure of his attainments. So that we rather say with Galen—that man had hands given to him, because he was the wisest creature, than to ascribe his superiority and knowledge to the use of his hands.*

This question has arisen from observing the perfect correspondence between the propensities of animals and their forms and outward organization. When we see a heron standing by the water side, still as a gray stone, and hardly distinguishable from it, we may ascribe this habit to the acquired use of its feet, constructed for wading, and to its long bill and flexible neck; for the neck and bill are as much suited to its wants, as the lister is to the fisherman. But there is nothing in the configuration of the black bear particularly adapted to catch fish; yet he will sit on his hinder extremities by the side of a stream, in the morning or evening, like a practised fisher; there he will watch, so motionless as to deceive the eye of the Indian, who mistakes him for the burnt trunk of a tree; and with his fore paw he will seize a fish with incredible celerity. The exterior

* Ita quidem sapientissimum animalium est homo; ita autem et manus sunt organa sapienti animali convenientia. Non enim quia manus habuit propterea est sapientissimum, ut Anaxagoras dicebat: sed quia sapientissimum erat, propter hoc manus habuit, ut rectissime censuit Aristoteles. Non enim manus ipsæ homines artes docuerunt, sed ratio. Manus autem ipsæ sunt artium organa: sicut lyra, musici, et forceps, fabri.

organ is not, in this instance, the cause of the habit or of the propensity; and if we see the animal in possession of the instinct without the appropriate organ, we can the more readily believe that, in other examples, the habit exists with the instrument, although not through it.

The canine teeth are not given without the carnivorous appetite, nor is the necessity of living by carnage joined to a timid disposition; but boldness and fierceness, as well as cunning, belong to the animal with retractile claws and sharp teeth, and which prey on living animals.* On the other hand, the timid vegetable feeder has not his propensities produced by the erect ears and prominent eyes; though his disposition corresponds with them in his suspiciousness and timidity. The boldness of the bison or buffalo may be as great as that of the lion; but the impulse is different—there is a direction given to him by instinct to strike with his horns: and he will so push whether he has horns or no. "The young calf will butt against you before he has horns," says Galen: and the Scotch song has it "the putting cow is ay a doddy," that is, the humble cow (*inermis*), although wanting horns, is always the most mischievous. When that noble animal, the Brahmin bull, of the Zoological Gardens, first put his hoof on the sod and smelt the fresh grass after his voyage,—placid and easily managed before, he became excited, plunged, and stuck his horns into the earth, and ploughed up the ground on alternate sides, with a very remarkable precision. This was his dangerous play; just as the dog, in his gambols, worries and fights: or the cat, though pleased, puts out its claws. It would, indeed, be strange, where all else is perfect, if the instinctive character or disposition of the animal were at variance with its arms or instruments.

But the idea may still be entertained that the accidental use of the organ may conduce to its more frequent exercise and to the production of a corresponding disposition. Such an hypothesis would not explain the facts. The late Sir Joseph Banks, in his evening conversations, told us that he had seen, what many, perhaps, have seen, a chicken catch at a fly whilst the shell stuck to its tail. Sir Humphry Davy relates that a friend of his having discovered under the burning sand of Ceylon, the eggs of the alligator, he had the curiosity to break one of them; when a young alligator came forth, perfect in its motions and in its passions; for although hatched under the influence of the sunbeams in the burning sand, it made towards the water, its proper element: when hindered, it assumed a threatening aspect and bit the stick presented to it. As propensities to certain motions are implanted in animals, to which their external

* In some of the quadrumana, the canine teeth are as long and sharp as those of the tiger—but they are in them only instruments of defence, and have no relation to the appetite, or mode of digestion, or internal organization.

organs are subservient, so are passions given as the means of defence or of obtaining food. But this has been well said seventeen hundred years ago. "Take," says Galen, "three eggs, one of an eagle, another of a goose, and a third of a viper; and place them favourably for hatching. When the shells are broken, the eaglet and the gosling will attempt to fly; while the young of the viper will coil and twist along the ground. If the experiment be protracted to a latter period, the eagle will soar to the highest regions of the air, the goose betake itself to the marshy pool, and the viper will bury itself in the ground."

When we direct the inquiry to the comparison of man's faculties with his outward organization, the subject has increased interest. With the possession of an instrument like the hand there must be a great part of the organization, which strictly belongs to it, concealed. The hand is not a thing appended, or put on, like an additional movement in a watch; but a thousand intricate relations must be established throughout the body in connexion with it—such as nerves of motion and nerves of sensation; and there must be an original part of the composition of the brain, which shall have relation to these new parts, before they can be put in activity. But even with all this superadded organization the hand would lie inactive, unless there were created a propensity to put it into operation.

I have been asked by men of the first education and talents whether anything really deficient had been discovered in the organs of the orang-outang to prevent him from speaking! The reader will give me leave to place this matter correctly before him. In speaking, there is first required a certain force of expired air, or an action of the muscles of respiration; in the second place, the vocal chords in the top of the wind-pipe must be drawn into accordance by their muscles, else no vibration will take place, and no sound issue; thirdly, the open passage of the throat must be expanded, contracted, or extended by their numerous muscles, in correspondence with the condition of the vocal chords or glottis; and these must all sympathise before even a simple sound is produced. But to articulate that sound, so that it may become a part of a conventional language, there must be added an action of the pharynx, of the palate, of the tongue and lips. The exquisite organization for all this is not visible in the organs of the voice, as they are called: it is to be found in the nerves which combine all these various parts in one simultaneous act. The meshes of the spider's-web, or the cordage of a man-of-war, are few and simple compared with the concealed filaments of nerves which move these parts; and if but one be wanting, or its tone or action disturbed in the slightest degree, every body knows how a man will stand with his mouth open, twisting his tongue and lips in vain attempts to utter a word.

It will now appear that there must be distinct lines of association suited to the organs of voice—different to combine them in the bark

of a dog, in the neighing of a horse, or in the shrill whistle of the ape. That there are wide distinctions in the structure of the different classes of animals is most certain; but independently of those which are apparent, there are secret and minute varieties in the associating cords. The ape, therefore, does not articulate—First, because the organs are not perfect to this end. Secondly, because the nerves do not associate these organs in that variety of action which is necessary to speech. And, lastly, were all the exterior apparatus perfect, there is no impulse to that act of speaking.

Now I hope it appears, from this enumeration of parts, that the main difference lies in the internal faculty or propensity. As soon as a child can distinguish and admire, then are its features in action: its voice begins to be modified into a variety of sounds; these are taken up and repeated by the nurse, and already a sort of convention is established between them. We cannot, therefore, doubt that a propensity is created in correspondence with the outward organs, and without which they would be useless appendages. The aptness of the instrument or external organ will undoubtedly improve the faculty, just as we find that giving freedom to the expression of passion adds force to the emotion in the mind.

One cannot but reflect here on that grand revolution which took place when the language, till then limited to its proper organ, had its representation in the work of the hand. Now that a man of mean estate can have a library of more intrinsic value than that of Cicero, when the sentiments of past ages are as familiar as those of the present, and the knowledge of different empires is transmitted and common to all, we cannot expect to have our sages followed, as of old, by their five thousand scholars. Nations will not now record their acts by building pyramids, nor consecrate temples and raise statues, once the only means of perpetuating great deeds or extraordinary virtues. It is in vain that our artists complain that patronage is withheld: for the ingenuity of the hand has at length subdued the arts of design—printing has made all other records barbarous, and great men build for themselves a " livelong monument."

Buffon has attempted to convey to us the mode in which knowledge may have been acquired by watching (in fancy) the newly awakened senses in the first created Man; but, for that which is consistent and splendid in our great poet—who makes him raise his wondering eyes to Heaven and spring up by quick instinctive motion as "thitherward endeavouring," he substitutes a bad combination of philosophy with eloquence.

"To place the subject more distinctly before us," says Buffon, "the first created man shall speak for himself;" and the sentence which he is made to utter is to the effect,—"that he remembers the moment of his creation—that time, so full of joy and trouble, when he first looked round on the verdant lawns and crystal fountains, and saw the vault of Heaven over his head;"—and he proceeds to de-

clare,—"that he knew not what he was or whence he came, and believed that all he saw was part of himself." He is thus represented to be conscious of objects, which even to see implies experience, and to enjoy, supposes a thousand disagreeable associations already formed:—but from this blissful state he is awakened by striking his head against a palm tree, which he had not yet learned could hurt him!

Men are diffident of their first notions, and conceive that philosophy must lead to something very different from what they have been early taught: hence the absurdity of this combination of philosophy and poetry. Later writers have argued that we have no right to suppose that there has been, at any time, an interruption to the course of nature. What they term the uniformity of nature, is the prevalence of the same laws which are now in operation. If, say they, it happened that on the arrival of a colony in a new country, fruits were produced spontaneously around them, and flowers sprung up under their feet, then, we might suppose that our first parents were placed in a scene of beauty and profusion—suited to their helpless condition—and unlike what we see now in the course of nature.

It is not very wise to entertain the subject at all, but if it is to be argued, this is starting altogether wide of the question. We do not desire to know how a tribe migrating westward could find sustenance, but in what state man could be created to live without a deviation from what is called the course of nature.

If man had been formed helpless as an infant, he must have perished; and if mature in body, he must have been created with faculties suited to his condition. A human being, pure from the Maker's hands, with desires and passions implanted in him, adapted to his state, and with a suitable theatre of existence, implies something very near what we have been early taught to believe.

In every change which the globe has undergone, we see an established relation between the animal created, and the elements around it. It is idle to suppose this a matter of chance. Either the structure and functions of the animal must have been formed to correspond with the condition of the elements, or the elements must have been controlled to minister to the necessities of the animal; and if the most careful investigation lead us to this conclusion, in contemplating all the inferior gradations of animal existence, what is it that makes us so unwilling to admit such an influence in the last grand work of creation?

We cannot resist those proofs of a beginning, or of design prevailing every where, or of a First Cause. When we are bold enough to extend our inquiries into the great revolutions which have taken place, whether in the condition of the earth or in the structure of the animals which have inhabited it, our notions of the uniformity of the course of nature must suffer some modification. Changes must, at certain epochs, have been wrought, and new beings brought into ex-

istence different from the order of things previously existing, or now existing: and such interference is not contrary to the great scheme of creation. It is not contrary to that scheme, but only to our present state. For the most wise and benevolent purposes, a conviction is implanted in our nature that we should rely on the course of events, as permanent and necessary. We belong to a certain epoch; and it is when our ambitious thoughts carry us beyond our natural condition, that we feel how much our faculties are constrained, and our conceptions, as well as our language, imperfect. We must either abandon these speculations altogether, or cease to argue purely from our present situation.

It has been made manifest that man and the animals inhabiting the earth have been created with reference to the magnitude of the globe itself;—that their living endowments bear a relation to their state of existence and to the elements around them. We have learnt that the system of animal bodies is simple and universal, notwithstanding the amazing diversity of forms that meet the eye—and that this system not only embraces all living creatures, but that it has been in operation at periods of great antiquity, before the last revolution of the earth's surface had been accomplished.

The most obvious appearances and the labours of the geologist give us reason to believe that the earth has not always been in the state in which it is now presented to us. Every substance which we see is compound; we nowhere obtain the elements of things: the most solid materials of the globe are formed of decompounded and reunited parts. Changes have been wrought on the general surface, and the proofs of these changes are as distinct as the furrows on a field are indicative that the plough has passed over it. The deeper parts of the crust of earth and the animal remains imbedded, also give proofs of revolutions: and that in the course of these revolutions there have been long periods or epochs. In short, progressive changes, from the lowest to the highest state of existence, of organization and of enjoyment, point to the great truth that there was a beginning.

When the geologist sees a succession of stratified rocks—the lowest simple, or perhaps chemical; the strata above these, compound; and successively others more conglomerated, or more distinctly composed of the fragments of the former—it is not easy to contradict the hypothesis of an eternal succession of causes. But there is nothing like this in the animal body, the material is the same in all, the general design too is the same: but each family, as it is created, is submitted to such new and fundamental arrangements in its construction as implies the presence of the hand of the Creator.

There is nothing in the inspection of the species of animals, which countenances the notion of a return of the world to any former condition. When we acknowledge that animals have been created in succession and with an increasing complexity of parts, we are not to

be understood as admitting that there is here proof of a growing maturity of power, or an increasing effort in the Creator; and for this very plain reason, which we have stated, that the bestowing of life or the union of the vital principle with the material body, is the manifestation of a power superior to that displayed in the formation of an organ or the combination of many organs, or construction of the most complex mechanism. It is not, therefore, a greater power that we see in operation, but a power manifesting itself in the perfect and successive adaptation of one thing to another—or vitality and organization to inorganic matter.

In contemplating the chain of animal creation, we observe that even now, there are parts of the earth's surface which are marshy, and insalubrious, and that these are the places inhabited by amphibious and web-footed animals,—such as are suited to the oozy margins of swamps, lakes or estuaries. It is most interesting to find that when the remains of animals of similar construction, are found in the solid rocks, the geologist discovers by other signs that at the period of the formation of these rocks, the surface was flat, and that it produced such plants as imply a similar state of the earth to these swampy and unhealthy regions.

We mark changes in the earth's surface, and observe, at the same time, corresponding changes in the animal creation. We remark varieties in the outward form, size and general condition of animals, and corresponding varieties in the internal organization,—until we find men created of undoubted pre-eminence over all, and placed suitably in a bounteous condition of the earth.

Most certainly the original crust of the earth has been fractured and burst up, so as to expose its contents; that they might be resolved and washed away, by the vicissitudes of heat, cold, and rain. Mountains and valleys have been formed; the changes of temperature in the atmosphere have ensured continual motion and healthful circulation: the plains have been made salubrious, and the damps which hung on the low grounds have gathered on the mountains in clouds, so that refreshing showers have brought down the soil to fertilize the plain; thus at once have been supplied the means for man's existence, with objects suited to excite his ingenuity, and to reward it, and fitted to develope all the various properties both of his body and of his mind.

There is extreme grandeur in the thought of an anticipating or prospective intelligence: in reflecting that what was finally accomplished in man, was begun in times incalculably remote, and antecedent to the great revolutions which the earth's surface has undergone. Nor are these conclusions too vast to be drawn from the examination of a part so small as the bones of the hand; since we have shown that the same system of parts which constitutes the perfection of that instrument adapted to our condition, had its type in the members of those vast animals which inhabited the bays, and

inland lakes of a former world. If we seek to discover the relations of things, how sublime is the relation established between that state of the earth's surface, which has resulted from a long succession of revolutions, and the final condition of its inhabitants as created in accordance with the change.

Nothing is more surprising to our measure of time, than the slowness with which the designs of Providence have been fulfilled. But as far as we can penetrate by the light of natural knowledge, the condition of the earth, and with it of man's destinies, have hitherto been accomplished in great epochs.

We have been engaged in comparing the structure, organs, and capacity of man and of animals—we have traced a relation—but we have also observed a broad line of separation: man alone capable of reason, affection, gratitude, and religion: sensible to the progress of time, conscious of the decay of his strength and faculties, of the loss of friends, and the approach of death.

One who was the idol of his day has recorded his feelings in nearly these words,—"We are as well as those can be who have nothing further to hope or fear in this world. We go in and out, but without the sentiments that can create attachment to any spot. We are in a state of quiet, but it is the tranquillity of the grave, in which all that could make life interesting to us is laid." If in such a state there were no refuge for the mind, then were there something wanting in the scheme of nature: an imperfection in man's condition at variance with the benevolence which is manifested in all other parts of animated nature.

ADDITIONAL ILLUSTRATIONS.

ADDITIONAL ILLUSTRATIONS.

THE MECHANICAL PROPERTIES OF THE SOLID STRUCTURE OF THE ANIMAL BODY CONSIDERED.

I YIELD to the suggestion of friends in further pursuing the subject of the solid textures of the animal frame, with the proofs of design which are exhibited in its mechanical provisions.

It has been shown in the first chapter that solidity and gravity are qualities necessary to every inhabitant of the earth: the first to protect it; the second, that the animal may stand, and possess that resistance, which shall make the muscles available for action.

The first material to be taken notice of, which bestows this necessary firmness on the animal textures, is the *cellular substance*. This consists of delicate membranes, which form cells; these cells communicate with each other, and the tissue thus composed enters every where into the structure of the animal frame. It constitutes the principal part of the *medusa*, which floats like a bubble on the water: and it is found in every texture of the human body. It forms the most delicate coats of the eye, and gives toughness and firmness to the skin. It is twisted into ligaments, and knits the strongest bones: it is the medium between bone, muscle, and blood-vessel: it produces a certain firmness and union of the various component parts of the body while it admits of their easy motion. Without it, we should be rigid, notwithstanding the proper organs for motion; and the cavities could not be distended or contracted, nor could the vessels pulsate.

But this cellular texture is not sufficient on all occasions, either for giving strength or protection: nor does it serve to sustain the weight, unless the animal live suspended in water, or creep upon the ground. We see, therefore, the necessity for some harder and more resisting material being added, if the weight is to rest on points or extremities; or if the muscular activity is to be concentrated.

Nature has other means of supplying the fulcrum and lever, besides the bones, or true skeleton, which we have been examining in the first part of this volume: and perhaps we shall find that there may be a system of solid parts superior to what we have been studying in the *vertebrata*.

The larvæ of proper insects and the annelides have no exterior members for walking or flying: but to enable them to creep, they must have points of resistance, or their muscles would be useless.

Their skins suffice; they are hardened by a deposite within them for this purpose; but if this skin were not further provided, it would be rigid and unyielding, and be no substitute for bone. These hardened integuments are, therefore, divided into rings; to these the muscles are attached; and as the cellular membrane between the rings is pliant, these annelides can creep and turn in every direction.

Without further argument, we perceive how the skin, by having a hard matter deposited in it, is adapted to all the purposes of the skeleton. It is worthy of notice that some animals, still lower in the scale,—the tubipores, sertularia, cellularia, &c., exhibit something like a skeleton. They are contained within a strong case from which they can extend themselves: whilst the corals and madrepores, on the other hand, have a central axis of hard material, the soft animal substance being, in a manner, seated upon it. But these substitutes for the skeleton are, like shell, foreign to the living animal; although in office they may resemble bone in sustaining the softer substance and giving form.

In the proper insect I should say that there is a nearer approach to a skeleton, did it not appear that the apparatus is more perfect than in some of the animals which have a true skeleton. The resisting material is here deposited externally, and is converted to every purpose which we have seen attained by means of the skeleton. Distinct members are formed, with the power of walking, leaping, flying, holding, spinning, and weaving. The hardened integuments, thus articulated and performing the office of bones, have, like them, spines and processes: with this difference, that their aspect is towards the centre, instead of projecting exteriorly. Were we to compare the system of "resisting parts" in man and in the insect, we should be forced to acknowledge the mechanical provisions to be superior in the lower animal! The first advantage of the skeleton (as we may be permitted to call the system of hard parts in the insect) being external and lifeless, is, that it is capable of having greater hardness and strength bestowed upon it, according to the necessities of the animal, than can be bestowed upon bone: true bone being internal and growing with the animal, is penetrated with blood-vessels; and therefore must be porous and soft. The next advantage is mechanical. The hard material is strong to resist fracture, and to bear the action of muscles, in proportion to its distance from the centre: for the muscles in the insect, instead of surrounding the bones, as in the higher animals, are contained within the shell, and the shell is, consequently, so much the further thrown off from the axis.

When considering the larger vertebral animals, we had reason to say that there is a correspondence between the resistance of the bones and the power of the muscles, and we may indulge the same reflection here. As the integument covering the insect is much

harder than bone, so are the muscles stronger, compared with the muscles of the vertebrata. From the time of Socrates, comparisons have been made between the strength of the horse and of the insect: to the obvious superiority of the latter.

As goodly a volume has been written on the muscles of a caterpillar as has ever been dedicated to the human myology. A very minute anatomical description has been made of the caterpillar which feeds upon the willow; and here we see that the annular construction of the hard integument determines the plan of the whole anatomy: the arrangement of the muscles, and the distribution of the nerves. Each ring has its three sets of muscles; direct, oblique, traversing and interweaving, but yet distinct and symmetrical: and all as capable of being minutely described as those of the human body have been by Albinus.* Corresponding with these muscles, the system of nerves is delicately laid down. In short, we allow ourselves to be misled in supposing that animals, either of minute size or low in the scale of arrangement, exhibit any neglect or imperfection. Even if they were more simple in structure, the admiration should be the greater: since they have all the functions in full operation which are necessary to life.

We may perceive that a certain substance calculated to sustain the more strictly living part, and to give strength, may be traced through all living bodies. In the vegetable it is the woody fibre: and there, sometimes, as if to mark the analogy, we may find silicious earth deposited instead of the phosphate and carbonate of lime of the animal structure. In the lower animals we find membranes capable of secreting a solid material, and although in some instances the substance is like leather or cartilage, it is in general earthy, and for the most part, carbonate of lime. But when elasticity is necessary, as well as general resistance, cartilage is employed, which is a highly comprehensible and elastic substance. Thus, in fishes, there is a large proportion of cartilage in their bones, and from this greater quantity, some have been called cartilaginous in distinction to the osseous or true fishes. The cartilaginous and elastic skeleton is brought into use in an unexpected manner: when the salmon or trout leaps from the water, the muscles bend the elastic spine,—which recoils in aid of the muscles of the opposite class: and thus these two forces combine to give a powerful stroke with the tail on the water.

MECHANICAL PROPERTIES IN BONE OR IN THE TRUE SKELETON.

These considerations lead us the more readily to understand the composition of bone; which is a combination of three parts having

* The work referred to is by Lyonnet, who reckons four thousand and sixty-one muscles in this caterpillar. He was, I think, a lawyer, with little to do.

different properties,—membrane, phosphate of lime, and cartilage. By these it is enabled to resist stretching, compression, and tortion. If bone had a superabundance of the earthy parts, it would break like a piece of porcelain; and if it did not possess toughness and some degree of elasticity, it would not enable a man to pull and push and twist.

Looking to the dense bone, we should hardly suppose that it was elastic; but if ivory be possessed of elasticity, it cannot be denied to bone. Now if a billiard ball be put upon a marble slab which has been painted, a very small spot will mark where the contact has been; but if we let the ball drop upon the marble from a height, we shall find the spot much larger, and that the elasticity of the ivory has permitted the ball to yield and momentarily to assume an oblate spheroidal form.

When a new principle is admitted into a complex fabric, the utmost ingenuity can hardly anticipate all the results. Elasticity is extensively employed in the machinery of the animal body; and to show how finely it must be apportioned, we shall take the instance of a bridge built with iron instead of stone, and having a certain swing and elasticity. It lately happened that a bridge of this kind fell in very curious circumstances,—by the marching of a body of soldiers over it. Now the bridge was calculated to sustain a greater weight than this body of men: and had they walked tumultuously over it, it would have withstood the pressure: but the soldiers marching to time, accumulated a motion, aided by the elasticity of the material, which broke it down. This leads us to form a conception of the necessity of the fine adjustment of the material in the animal fabric; not merely to enable it to sustain the incumbent weight, or transverse or oblique impulses, but to withstand the frequent, and regularly repeated forces to which it may be subject in the various actions of the body. It gives interest to this fact, that there is hardly a bone but what has a constitution of its own, adjusted to its place and use: the heel bone, the shin bone, the vertebræ, and the bones of the head, differ in mechanical construction. But the consideration of these adaptations in the constitution of the bones makes some general remarks necessary.

Perfect security against accidents in the animal body, and in man especially, is not consistent with the scheme of nature. Without the precautions and the continued calls to exertion, for safety, which danger and the uncertainty of life produce, many of the faculties of the mind would remain unexercised; and whence else would come courage, resolution, and all the manly virtues? Take away the influence of the uncertain duration of life, and we must suppose also a change in the whole moral constitution of man. Whether we consider the bones as formed to protect the part, as in the skull: or to be levers to which the muscles are attached, as in the limbs: or in both capacities, as in the texture of

the chest: while they are perfectly adapted to their function, they are yet subject to derangements from accident. The mechanical adaptations which we have to observe are perfectly sufficient to their ends, and afford safety in the natural exercises of the body. To these exercises there is an intuitive impulse, ordered with a relation to the frame of the body; whilst, on the other hand, we are deterred from the excessive or dangerous use of the limbs by the admonitions of pain. Without such considerations, the reader would fall into the mistake that weakness and liability to fracture implied imperfection in the frame of the body: whereas a deeper contemplation of the subject will convince him of the incomparable perfection both of the plan and of the execution. The body is intended to be subject to derangement and accident, and to become, in the course of life, more and more fragile, until by some failure in the frame-work or vital action, life terminates.

The bones of the extremities are called hollow cylinders. Now, after we have convinced ourselves of the necessity of this formation, we find these bones, upon a more particular examination, extremely varied in their shapes: and we are, at last, prone to believe that there is much of chance or irregularity in their shapes: but such a conception is quite inconsistent with a correct knowledge of the skeleton. As this notion, however, is very commonly entertained and leads to further mistakes, we shall take pains to show,—first, why the bones are hollow; and, in the second place, why they vary in their shape, so as to appear to the superficial observer irregular.

The reasoning that applies to the hollow cylindrical bone serves equally to explain many other natural forms, as that of a quill, a reed, or a straw. The last example reminds us of the unfortunate man who was drawn from his cell before the Inquisition, and accused of having denied that there was a God; when picking up a straw that had stuck to his garments, he said, "If there were nothing else in nature to teach me the existence of a Deity, this straw would be sufficient." It hardly requires demonstration to prove that, with a given mass of material to make a pillar or column, the hollow cylinder will be the form of strength. The experiments of Du Hamel on the strength of beams affords us the best illustration how the material should be arranged to resist transverse fracture. When a beam rests on its extremities, bearing a weight upon its centre, it admits of being divided into three portions; for these three parts are in a different condition with regard to the weight. The lower part resists fracture by its toughness: the upper part, by its density and resistance to compression: but there is a portion between these which is not acted upon at all; which might be taken away without any considerable weakening of the beam: and which might be added to the upper or the lower part with great advantage. It can readily be understood how a

tougher substance added to the lower part would strengthen the beam: we see it in the skin which is laid along the back part of the Indian's bow; or in the leather of a carriage spring: but the following is a beautiful experiment to demonstrate that quality in the timber which resists, at the upper portion of the beam. If a portion amounting to nearly a third part of the beam be cut away and a harder piece of wood be nicely let into the space, the strength will be increased; because the hardness of this piece of wood resists compression. This experiment I like the better because it explains a very interesting peculiarity in the different densities of the several parts or sides of the bones. In reading anatomical books, we are led to the supposition that the various forms of the bones result from the pressure of the muscles. This is a mistake. Were we to consider this the true explanation, it would not only be admitting an imperfection, but we should expect to find, if the bones yielded in any degree to the force of the muscles, that they would yield more and more, and be ultimately destroyed. There is nothing more admirable in the living frame than the relation established between the muscular power and the capacity of passive resistance in the bones. The deviations from the cylindrical forms are not irregularities; and if we take that bone which deviates the furthest from the cylindrical shape, the tibia, or shin bone, we shall have demonstration of the relation between the shape of the bone and the force which it has to sustain.

If we consider the direction of the force in walking, running, or leaping, and in all the powerful exertions where the weight of the body is thrown forwards on the ball of the great toe, it must appear that the pressure against this bone is chiefly on the anterior part: and there is no doubt that if the tibia were a perfect cylinder, it would be subject to fracture even with the mere force of the body itself thrown upon it. But if, as we have stated, the column is stronger in proportion as the material is distant from the centre, we readily perceive how an anterior spine or ridge, should be thrown out: and if we attend to the internal structure of that spine, we shall find that it is much denser and stronger than the rest of the bone. We cannot here deem either the form or the density of this ridge, a thing of accident; since it so perfectly corresponds with the experiment of Du Hamel which we have described, where the dense piece of wood being let into the piece of timber, it was found to be a means of resisting transverse fracture. If we proceed with the knowledge of these facts to the examination of the different bones of the skeleton, we shall find that every where the form has a strict relation either to the motion to be performed, or the strain to which the bone is liable.

In comparing the true bones with the coverings of the insects, we observed the necessity for the porous structure of the former. If it be necessary that the bone shall be very dense, it will no longer

be possessed of the power of reunion or reproduction when it breaks: it will not re-unite upon being fractured, and if exposed, it will die. Here, then, is an obvious imperfection. The bones of animals cannot, in this manner, be made capable of sustaining great weight, without losing a property which is necessary to their existence—that of restoration on their being injured. And even were the material very much condensed, it does not appear that the phosphate of lime, united as it is with the animal matter, is capable of sustaining any great weight; this accordingly limits the size of animals. It may, perhaps, countenance the belief that animals bear a relation in their size and duration of life, to the powers and life of man, that the larger animals have existed in a former condition of the world. We allude only to such animals as have extremities: for with respect to the whale, its huge bulk lies out supported on the water. The iguanadon, discovered by Mr. Mantell, is estimated to have been seventy feet in length, and to have had extremities. But the thigh and leg did not exceed eight feet in length, while the foot extended to six feet; a proportion, altogether, which implies that the extremities assisted the animal to crawl, rather than that they were capable of bearing its weight, as the extremities of the mammalia. However, we find that in the larger terrestrial animals, the material of the bones is dense, and that their cavities are filled up: the diameters of those of the extremities, with their spines and processes being remarkably large. Nothing can be conceived more clumsy than the bones of the megatherium: so that it appears that nature has exhausted her resources with respect to this material; and that living and vascular bone could not be moulded into a form to sustain the bulk and weight of an animal much superior to the elephant, mastodon, and megatherium.*

With regard to the articulation of the bones, we cannot mistake the reason of the surfaces of contact being enlarged. In machinery it is found that, if the pressure be the same, the extension of the surfaces in contact does not increase the friction. If, for example, a

* The subject may be illustrated in this manner:—" A soft stone projecting from a wall, may make a stile strong enough to bear a person's weight; but if it were necessary to double the length of the stile, the thickness must be more than doubled, or a freestone substituted; and were it necessary to make this freestone project twice as far from the wall, even if doubled in thickness, it would not be strong enough to bear a proportioned increase of weight: granite must be placed in its stead; and even the granite would not be capable of sustaining four times the weight which the soft stone bore in the first instance. In the same way the stones which form an arch, of a large span, must be of the hardest granite, or their own weight would crush them. The same principle is applicable to the bones of animals. The material of bone is too soft to admit an indefinite increase of weight; and it is another illustration of what was before stated, that there is a relation established through all nature: that the very animals which move upon the surface of the earth are proportioned *to its magnitude*, and the gravitation to its centre."—Animal Mechanics.

stone or a piece of timber, of the shape of a book or a brick, should be laid upon a flat surface, it would be drawn across it with equal facility, whether it rested upon its edge or upon its side. The friction of the bones which enter into the knee joint is not increased by their greater diameter; while great advantages are gained; the ligaments which knit these bones give more strength than they otherwise would, and the tendons which run over them, being removed to a distance from the centre, have more power.

THE MUSCULAR AND ELASTIC FORCES.

The muscular power is contrasted with the elastic, as possessing a living property of motion. We acquiesce in the distinction, since the muscular fibre ceases to have irritability or power in death, while elasticity continues in the dead part. But yet there is a property of elasticity in the living body which cannot be retained after death. To illustrate this we shall take the instance of the catgut string of a harp. Suppose that the string is screwed tight, so as to vibrate in a given time, and to sound the note correctly; if that string be struck rudely, it is put out of tune; that is, it is stretched and somewhat relaxed, and no longer vibrates in time. This does not take place in the living fibre: for here there is a property of restoration. If we see the tuner screwing up the harp string, and with difficulty, and after repeated attempts, bringing it to its due tension,—trying it with the tuning fork, and with his utmost acquired skill restoring it to its former elasticity, we have a demonstration of how much life is performing in the fibres of the animal frame, after every effort or exertion; and the more powerful the mechanical parts of the body are, the more carefully is the proper tension of the tendons, ligaments, and heart-cords preserved. Or we may take the example of a steel spring. A piece of steel, heated to a white heat, and plunged into cold water, acquires certain properties; and if heated again to 500 of Fahrenheit, it is very elastic; possessing what is called a "spring temper," so that it will recoil and vibrate. But if this spring be bent in a degree too much, it will lose part of its elasticity. Should the parts of the living body, on the other hand, be thus used, they have a power of restoration which the steel has not.

If a piece of fine mechanism be made perfect by the workman, it may be laid by and preserved; but it is very different with the animal body. The mechanical properties of the living frame, like the endowments of the mind, must not lie idle, or they will suffer deterioration. If, by some misfortune, a limb be put out of use, not only is the power of the muscles rapidly diminished, which every one will acknowledge, but the property of resistance is destroyed; and bones, and tendons, and ligaments quickly degenerate.*

* This subject is illustrated in the Essay on Animal Mechanics, Part. II.

A COMPARISON OF THE EYE WITH THE HAND.

If we are in search of an object which shall excite the highest interest, and at the same time afford proofs of design in the most delicate of all the organs of the body, we naturally turn to the eye: and this organ suits our present purpose the better, that we have to show how much of the sense of vision depends on the hand, and how strict the analogy is between the two organs.

From the time of Sir Henry Wotton to the latest writer on light, the eye has been a subject of admiration and eulogy. But I have ventured, on a former occasion,* to say, that this admiration is misplaced, while it is given to the ball of the eye and the optic nerve exclusively; since the high endowments of this organ belong to the exercise of the whole eye, to its exterior apparatus, as much as to its humours and the proper nerve of vision. It is to the muscular apparatus, and to the conclusions which we are enabled to draw from the consciousness of muscular effort, that we owe that sense by which we become familiar with the form, magnitude, and relations of objects. One might as well imagine that he understood the effect and uses of a theodolite, on estimating the optical powers of the glasses, without looking to the quadrant, level, or plumb-line, as suppose that he had learnt the whole powers of the eye by confining his study to the naked ball.

We must begin our observations by a minute attention to the structure and sensibility of the retina. The retina is the internal coat of the eye; it consists of a delicate, pulpy, nervous matter, which is contained between two membranes of extreme fineness, and these membranes both support it and give to its surfaces a mathematical correctness. The matter of the nerve, as well as these supporting membranes, are perfectly transparent, during life; and on the axis of the eye, there is a small portion which remains transparent, when the rest of the membrane becomes opaque, and which has been mistaken for a foramen,† or hole in the retina. It is surprising, that with all the industry which has been employed to demonstrate the structure of the eye, it is only in the present day that a most essential part of the retina has been discovered—the membrane of Mr. Jacob. From observing the phenomena of vision, and especially the extreme minuteness of the image cast upon the retina, I had conceived that the whole nerve was not the seat of vision, but only one or other of its surfaces. This could not be well illustrated until the exterior membrane of the retina was demonstrated. But now we see that this membrane, when floated in water and under a magnifying glass, is of extreme tenuity, and

* See Philosophical Transactions.

† It is this part which is called the foramer of Soemmerring.

its smooth surface is well calculated to correspond with the exterior surface of that layer of nervous matter which is the seat of the sense.

The term retina would imply that the nerve constitutes a network: and the expressions of some of our first modern authorities would induce us to believe that they view it in this light, as corresponding with their hypothesis. But there is no fibrous texture in the matter of the nerve; although, when the retina is floated and torn with the point of a needle, the innermost of the membranes which support the nerve, the *tunica vasculosa retinæ*, presents something of this appearance.

Vision is not excited by light unless the rays penetrate through the transparent retina and reach the exterior surface from within.

It is well known, that if we press upon the eye-ball with a key or the end of a pencil-case, zones of light are excited. The perception of that light is, as if the rays came in a direction opposite to the pressure. We may say that, in this case, the effect of the pressure is assimilated to that of light; and as light can strike the part of the nerve which is pressed, only by coming in an opposite direction, the zones of light produced by the mechanical impulse appear in the usual direction of rays impinging upon this part: and consequently, they give the impression of their source being in the opposite quarter. Let us contrast this phenomenon with the following experiment. Close the eyelids, and cover them with a piece of black cloth or paper which has a small hole in it; and place this hole, not opposite to the pupil, but to the white of the eye; direct a beam of light upon the hole; a person will see this light in its true direction. Why should there be in these two cases a difference in the apparent place from which the light is derived? were it not that the rays of light directed upon the eye-ball, after striking upon the retina, pierce through it and through the humours of the eye, and impinge upon the retina on the opposite side. This explains why the light excited in the eye shall appear to come from different quarters; but it does not explain why there should not be a double impression—why the beam of light should not influence the retina while penetrating it in the first instance, that is in passing through it from without inwards, as well as when it has penetrated the humours and strikes upon the opposite part of the retina from within outwards.

Another fact, which has surprised philosophers, is the insensibility of the optic nerve itself to light. If it be so contrived that the strongest beam of light shall fall upon the end of the nerve at the bottom of the eye, where it begins to expand into the delicate retina, no sensation of light will be produced. This ought not to surprise us, if I am correct in my statement that the gross matter of the nerve is not the organ of vision, but the exterior surface of it only. In the extremity of the optic nerve there is, of course, no posterior surface; and, indeed, nothing can better prove the distinct

office of the nerve as contrasted with the expanded retina, than this circumstance, that when the strongest ray of light strikes into the nerve itself, the impression is not received. It seems to imply, that the capacity of receiving the impression, and of conveying it to the sensorium, are two distinct functions.

Is not this opinion more consistent with the phenomena than what is expressed by one of our first philosophers, that the nerve, at its extremity towards the eye, forms what has been called the *punctum cœcum,* and is insensible, because it is not yet divided into those almost infinitely minute fibres which are fine enough to be thrown into tremors by the rays of light.

Independently of this punctum cœcum, we have to observe that the whole surface of the retina is not equally sensible to light. There is a small spot, opposite to the pupil and in the axis of the eye, which is more peculiarly sensible to visual impressions. An attempt has been made to ascertain the diameter of this spot; and it is said, that a ray at an angle of five degrees from the optic axis, strikes exterior to this sensible part. But we shall, on the contrary, see reason to conclude, that the sensible spot is not limited to an exact circle, that it is not regularly defined, and that the sensibility, in fact, is increasing to the very centre.

Some have denied the existence of this extreme sensibility in the centre of the retina, attributing the distinctness of the vision to the circumstance of the light being made to converge through the influence of the humours, more correctly to this point. I shall, therefore, show how impossible vision would be, were it not that the sensibility of the retina increases gradually from its utmost circumference to the point which forms the axis of the eye.

We see objects by reflected light, at the very instant that direct light enters the eye. As the impression by the direct light is many times stronger than the reflected rays from the object, the vision of the object would be destroyed by the contrast, were there not this admirable provision in the retina, that the direct light shall fall upon a part less sensible, the reflected light upon a part more sensible. If, in full day, and in the open field, the eye be directed southward, the rays from the sun enter the eye at the time that we are looking to certain objects. It is perfectly clear, that if the sun's rays struck a part of the retina as sensible as the spot in the centre or axis, it would extinguish all secondary impressions: the glare would be painfully powerful, as when we look directly to the sun. If a momentary glance to the sun produce a sensation so acute that we see nothing for some time after, would not the same happen were the retina equally sensible in all its surface? A similar thing takes place in a chamber lighted with candles ; we do not see the person immediately on the other side of the candle: for there the direct light interferes with the reflected light, effacing the slighter impression of the latter.

We perceive, therefore, that if the retina were equally sensible over all its surface we could not see. Let us, then, observe how we do actually see, and how the organ is exercised. There is a continual desire of exercising the sensible spot, the proper seat of vision. When an impression is made upon the retina, in that unsatisfactory degree, which is the effect of its striking any part but the centre, there is an effort made to direct the axis towards it, or, in other words, to receive the rays from it upon the more sensible centre. It is this sensibility, therefore, conjoined with the action of the muscles of the eye-ball, which produce the constant searching motion of the eye; so that, in effect, from the lesser sensibility of the retina generally, arises the necessity for this exercise of the organ; and to this may be attributed the high perfections of it.

This faculty of searching for the object is slowly acquired in the child: and in truth, the motions of the eye are made perfect, like those of the hand by slow degrees. In both organs there is a compound operation:—the impression on the nerve of sense is accompanied with an effort of the will, to accommodate the muscular action to it. It is no contradiction to this, that the faculty of vision is made perfect in the young of some animals from the beginning; no more than the instinct of the duck, when it runs to the water the moment that the shell is broken, contradicts the fact that the child learns to stand and walk after a thousand repeated efforts.

Let us now see how essential this searching motion of the eye is to vision. On coming into a room, we see the whole side of it at once—the mirror, the pictures, the cornice, the chairs; but we are deceived: being unconscious of the motions of the eye, and that each object is rapidly, but successively, presented to it. It is easy to show, that if the eye were steady, vision would be quickly lost: that all these objects, which are distinct and brilliant, are so from the motion of the eye: that they would disappear if it were otherwise. For example, let us fix the eye on one point, a thing difficult to do, owing to the very disposition to motion in the eye: but by repeated attempts we may at length acquire the power of fixing the eye to a point; and when we have done so, we shall find, that the whole scene becomes more and more obscure, and finally vanishes. Let us fix the eye on the corner of the frame of the principal picture in the room. At first, everything around it is distinct; in a very little time, however, the impression becomes weaker, objects appear dim, and then the eye has an almost incontrollable desire to wander; if this be resisted, the impressions of the figures in the picture first fade: for a time, we see the gilded frame: but this also becomes dim. When we have thus far ascertained the fact, we change the direction of the eye, but ever so little, and at once the whole scene is again perfect before us.

These phenomena are consequent upon the retina being subject to exhaustion. When a coloured ray of light impinges continuously

on the same part of the retina, it becomes less sensible to it, but more sensible to a ray of the opposite colour. When the eye is fixed upon a point, the lights, shades, and colours of objects continuing to strike upon the same relative parts of the retina, the nerve is exhausted: but when the eye shifts, there is a new exercise of the nerve: the part of the retina that was opposed to the lights, is now opposed to the shades, and what was opposed to the different colours is now opposed to other colours, and the variation in the exciting cause produces a renewed sensation. From this it appears, how essential the incessant searching motion of the eye is to the continued exercise of the organ.

Before dismissing this subject, we may give another instance. If we are looking upon an extensive prospect, and have the eye caught by an object at a distance, or when, in expectation of a friend, we see a figure advancing on the distant road, and we endeavour to scrutinize the object, fixing the eye intently upon it, it disappears; in our disappointment we rub the eyes, cast them about, look again, and once more see the object. The reason of this is very obvious: the retina is exhausted, but becomes recruited by looking on the other objects of different shades and colours. The sportsman on the moor or the hill side, feels this a hundred times when he marks down his covey, fixing his eye and travelling towards the spot.

Here we may interrupt our inquiry to observe how inconsistent these phenomena are with the favourite hypothesis—that the light produces vision by exciting vibration in the fibres of the nerve. By all the laws of motion from which this hypothesis is borrowed, we know that if a body be set in motion, it is easily kept in motion; and that if a chord vibrate, that vibration will be kept up by a motion in the same time. It appears to me natural to suppose, that if these fibres of the nerve (which, be it remembered, are also imaginary) were moved like the cords of a musical instrument, they would be most easily continued in motion by undulations in the same time: that if the red ray oscillated or vibrated in a certain proportion of time, it would keep the fibres of the nerve in action more easily, than a green ray, which vibrates in a different time. If the colour of a ray depended upon the peculiar undulation or vibration, it appears that before the green ray could produce a motion corresponding with itself, it must encounter a certain opposition, in interrupting the motion already begun.*

* "Although any kind of impulse or motions regulated by any law may be transferred from molecule to molecule in an elastic medium, yet, in the theory of light it is supposed that only such primary impulses, as recur according to regular periodical laws at intervals of time and repeated many times in succession, can affect our organs with the sensation of light. To put in motion the molecules of the nerves of our retina with sufficient efficacy, it is necessary that the almost infinitely minute impulse of the adjacent ethereal molecules should be often and regularly repeated, so as to multiply and concentrate their effect. Thus, as a great pendulum may be set in swing by a very minute force, often applied at intervals exactly

Reverting to the sensible spot in the retina, it does not appear that we are authorized in terming it a spot. The same law governs vision when we look to a fine point of a needle, or to an object in an extensive landscape. We look to the point of a pen, and we can rest the attention on the point upon the one side of the slit, to the exclusion of the other, just as we can select and intently survey a house or a tree. If the sensible spot were regularly defined, it must be very small: and were it, indeed, so defined, we should be sensible of it; which we are not. The law, therefore, seems to be, at all times, that the nearer to the centre of the eye, the greater the sensibility to impression; and this holds whether we are looking abroad in the country, or are microscopically intent upon objects of great minuteness.

When men deny the fine muscular adaptation of the eye to the sensation on the retina, how do they account for the obvious fact—that the eye-ball does move in such just degrees? how is the one eye adjusted to the other with such marvellous precision? and how do the eyes move together in pursuit of an object, never failing to accompany it correctly, be it the flight of a bird, or the course of a tennis-ball, or even of a bomb-shell? Is it not an irresistible conclusion—that if we so follow an object, adjusting the muscles of the eye so as to present the axis of vision successively to it, as it changes place, we must be sensible of these motions? for how can we direct the muscles unless we be sensible to their action? The question then comes, to be—whether being sensible to the condition of the muscles, and being capable of directing them with this extraordinary minuteness, this action of the muscles does not enter into our computation of the place of an object? But is not this exactly the same question recurring as when we ask—whether we can direct the hand without knowing where the hand is? Must there not be a feeling or knowledge of the position of the hand, before we can give it direction to an object? And must we not have a conception of the relation of the muscles and of the position

equal to its time of oscillation, or as one elastic body can be set in vibration, by the vibration of another at a distance propagated through the air, if in exact unison, even so we may conceive the gross fibres of the nerves of the retina to be thrown into motion by the continual repetition of the ethereal pulses; and such only will be thus agitated, as from their size, shape or elasticity, are susceptible of vibrating in times exactly equal to those at which the impulses are repeated. Thus it is easy to conceive how the limits of visible colour may be established: for if there be no nervous fibres in unison with vibrations more or less frequent than certain limits, such vibrations, though they reach the retina, will produce no sensation. Thus, too, a single impulse, or an irregularly repeated one, produces no light. And thus also may the vibrations excited in the retina continue a sensible time after the exciting cause has ceased, prolonging the sensation of light (especially if a vivid one) for an instant in the eye in the manner described." Sir W. Herschell, Art. Light. Enc. Met.

Now it does appear to me that this reasoning is inconsistent with the phenomena above noticed.

of the axis of the eye, before we can alter its direction to fix it upon a new object?

It surprises me to find ingenuous men refusing their assent to the opinion, that the operation of the muscles of the eye is necessary to perfect vision, when the gradual acquisition of the power may be seen in observing the awakening sense in the infant. When a bright object is withdrawn from the infant's eye, there is a blank expression in the features; and an excitement when the object is again presented. For a time, the shifting of the object is not attended with the searching action of the eye: but by and by, the eye follows it and looks around for it, when it is lost. In this gradual acquisition of power in the eye, there is an exact parallel to the acquisition of motion in the hand; and in both instances, we seek to join the experience obtained by means of the muscular motion with the impression on the proper nerve of sense.

Some maintain that our idea of the position of an object is implanted in the mind and independent of experience. We must acknowledge the possibility of this, had it been so provided. We see the young of some creatures with their vision thus perfect at the moment of their birth. But in these animals, every corresponding faculty is, in the same manner, perfect from the beginning: the dropped foal, or the lamb, rises and follows its mother. We must no more compare the helpless human offspring with the young of these animals than with a fly, the existence of which is limited to an hour at noon,—which breaking from its confinement, knows its mate and deposites its eggs on the appropriate tree—the willow or the thorn, and dies. But this is foreign to our inquiry; since it is obvious that the human eye has no such original power of vision bestowed upon it, and that it is acquired, as the exercise of the other senses, and the faculties of the mind itself are by repeated efforts, or experience.

If it be admitted that the ideas which we receive through the eye come by experience, we must allow that the mind must be exercised in the act of comparison, before we can have a conception of anything being exterior to the eye, or of an object being placed in a particular direction. Authors make the matter complex by conceiving a picture to be drawn at the bottom of the eye, and presenting to us the mind contemplating this inverted picture, and comparing the parts of it. But this leaves the subject without any explanation at all, and does not show how it is that the mind looks into this camera. The question will be, at least, more simple, if we consider the vision of a point; and ask ourselves how we know the direction in which that point comes to the eye. Suppose it is a star in the heavens, or a beacon, seen by the mariner; must he not, in order to ascertain the position of the star, find out some other object of comparison, some other star, which shall disclose to him the constellation to which the one that

he is examining belongs: or to ascertain the position of the beacon, must he not look to his compass and card, and so trace the direction of the lighthouse in relation to them? This is, in fact, the process that is followed in everything which we see. A single point is directly in the axis of the eye, but we cannot judge of its position, without turning to some other point, and feeling sensible of the traversing of the eye-ball and the angle to which the eye is moved: or if we do not see another point to compare the first with, we must judge of its place by means of a comparison with the motion of the eye itself. We are sensible that the eye is directed to the right or to the left; and we compare the visible impression on the nerve with the motion, its direction, and its extent.

We find even mathematicians affirming that we judge of the direction of an object by the ray that falls upon the retina. But the ray which is here spoken of strikes a mere point of the retina: this point can have no direction; the obliquity of the incidence of the ray can inform us of nothing: rays of all degrees of obliquity are converging to form that point. And do not the same mathematicians give us, in the first lessons of their science, as the definition of a line, that which is drawn through two points at the least? Where are the two points here to indicate the direction of the line,—since the cornea, or the humours of the eye,* are not sensible to the passage of the ray? Or is this an error which has crept in from inaccurate conceptions of the anatomy? Has the idea that the direction of the ray can afford this knowledge, arisen from the notion that the ray passes through the thick and turbid matter of the retina? I would ask for what reason is the "finder" attached to the great telescope? is it not because the larger instrument from magnifying one object in a high degree, cannot be directed in the heavens, the observer seeing nothing but that one object? Accordingly to remedy this, there is mounted on the greater telescope a smaller one, exactly parallel, of lesser power, but commanding a greater field: this finder, the astronomer directs to the constellation and moves from star to star, until that which he desires to examine is in the centre of the field: and by this means he adjusts the larger telescope to his object. Is this not a correct illustration of the operation of the eye? is the eye not imperfectly exercised when it sees but one point—on the other hand, is it not in the full performance of its function when it moves from one object to the other, judges of the degree and the direction of that motion, and thus enables us, by comparison, to form our judgment?

It has been stated by a most ingenious philosopher of our own time, that the forms and relations of objects are known to us by

* See a paper by Mr. Alexander Shaw, who has explained this subject very happily.—Journal of the Royal Institution, 1832.

the unassisted operation of the eye-ball itself—by the transmission of the rays through the humours of the eye, and by their effect upon the retina; and he has also affirmed that we should know the position of objects even if the muscles of the eye were paralytic. But I hope that it has been understood, when I give so much importance to the motions of the eye, that I do not neglect the movements of the body, and, more especially, the motions of the hand: that, in truth, the measure of objects which we take through the eye, is in correspondence with the experience which we have had through the motions of the whole frame, and that, without such experience, we should have no knowledge of matter, or of position, or of distance, or of form. Were the eye fixed in the head, or paralytic, we should lose a great part of the exercise of the organ, as well as all the appliances which are necessary for its protection: but we should still be capable of comparing the visual impression with the experience of the body. As long as we know the right hand from the left, or must raise our head to see what is above us, or stoop to see a man's foot, there can be no want of materials to form a comparison between the impression on the nerve of sight and the experience of the body.

Against this view of the compound operation of the eye, the matter is thus argued:—if a man receive the impression of a luminous body upon his eye so that the spectrum shall remain when the eye-lids are shut, and if he be seated upon a stool that turns round, and he be whirled round by the hand of a friend, without his own effort, the motion of the spectrum will correspond with his own. No doubt it will: because he is conscious of being turned round; a man cannot sit upon a stool that is turning without an effort to keep his place, without a consciousness of being turned round; and feeling, at the same time, that the impression is still before his eye, he will see the spectrum before him, and in that aspect to which he has been revolved.

Were I not conscious that I am right, I should feel it necessary to make an apology for differing from eminent men on this matter: but I conceive the explanation of this discrepancy to be, that we are very much influenced by the manner in which we approach to the examination of such a subject. A man lost in admiration of the properties of light, and of the effect of the humours of the eye as an optical instrument, may be blinded to those inferences, which to me seem so undeniable, accustomed as I have been to compare the properties of the eye with the living endowments of the frame. When instead of looking upon the eye as a mere camera or show box, with the picture inverted on the bottom, we determine the value of muscular activity; mark the sensation attending the balancing of the body; that fine property which we possess of adjusting the muscular frame to its various inclinations; how it is acquired in the child; how it is lost in the paralytic and drunkard; how motion and sensation are combined in the hand; how,

in this way, the hand guides the finest instruments: when we consider how the eye and the hand correspond; how the motions of the eye, combining with the impression on the retina, become the means of measuring and estimating the place, form and distance of objects—the sign in the eye of what is known to the hand: finally, when, by attention to the motions of the eye, we are aware of their extreme minuteness, and how we are sensible to them in the finest degree—the conviction irresistibly follows, that without the power of directing the eye, (a motion holding a relation to the action of the whole body) our finest organ of sense, which so largely contributes to the developement of the powers of the mind, would lie unexercised.

THE MOTION OF THE EYE CONSIDERED IN REGARD TO THE EFFECT OF SHADE AND COLOUR IN A PICTURE.

A QUESTION naturally arises whether it be possible, from this part of philosophy, to suggest some principles for the amateur and painter. The ideas and language of the amateur, when he attempts to establish rules for the disposition of colours or shades in a picture are certainly very vague.

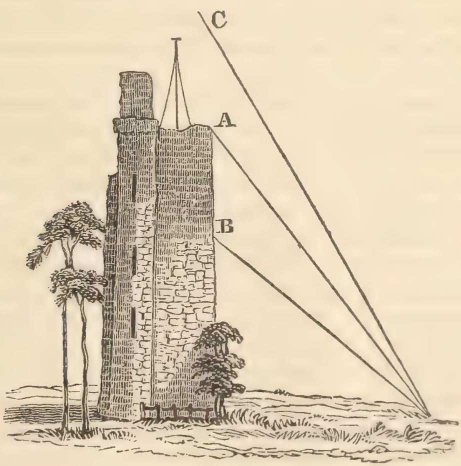
We have to remark, in the first place, that the colours of nature, and those of objects when represented in a painting, differ in most essential circumstances. Bodies of various colours, when placed together, have their colours reflected from the one to the other; and so they are sent to the eye. This is one mode in which the hues of nature are harmonized; but the colours upon the flat surface of the canvass cannot be thus reflected and mingled. The next difference results from the atmosphere, through which the rays from distant objects proceed to the eye and are softened; the canvass being near the eye, the effect which the atmosphere produces on colours amounts to nothing in the picture. The third mode in which colours are effected, is common to natural objects and to paintings, and is connected with the law of vision which we have been considering, and to which we must now revert.

When we make experiments by looking upon coloured spots, the effect on the sensibility of the retina is remarkable; and as this does not occur incidentally, but takes place, more or less, whenever we exercise the eye, it must have its influence when we look to works of art. The familiar fact which we have to carry with us into this inquiry, is, that if we throw a silver coin upon a dark table, and fix the eye upon the centre of it, when we remove the coin there is, for a moment, a white spot in its place, which presently becomes deep black. If we put a red wafer upon a sheet of paper, and look upon it, and continue to keep the eye fixed on the same point, upon removing the wafer, the spot where it lay on the white paper will appear green. If we look upon a green wafer in the same

manner and remove it, the spot will be red; if upon blue or indigo, the paper will appear yellow. These phenomena are to be explained by considering that the nerve is exhausted by the continuance of the impression, and becomes more apt to receive sensation from an opposite colour. All the colours of the prism come into the eye from the surface of the paper when the wafer has been removed; but if the nerve has been exhausted by the incidence of the red rays upon it, it will be insensible to these red rays when they are thus reflected from the paper; the effect of the rays of an opposite kind will be increased, and consequently the spot will be no longer white, but of the prevailing green colour.

Let us see how the loss of sensibility produces an effect in engraving, where there is no colour, and only light and shade.

Is it possible that a high tower in a cloudless sky, can be less illuminated at the top than at the bottom? Yet if we turn to a book of engravings, where an old steeple or tower is represented standing up against the clear sky, we shall find that all the higher part is dark, and that the effect is picturesque and pleasing. Now this is perfectly correct, for although the highest part of the tower be in the brightest illumination, it is not seen so—it never appears so to the eye. The reason is, that when we look to the steeple, a great part of the retina is opposed to the light of the sky; and on shifting the eye to look at the particular parts of the steeple, the reflected light from that object falls upon the retina, where it is exhausted by the direct light of the sky. If we look to the top of the tower, and then drop the eye to some of the lower architectural ornaments, the effect infallibly is that the upper half of the tower is



dark. For example, if looking to the point A we drop the eye to B: the tower from A to B is seen by that part of the retina which

was opposed to the clear sky from A to C; and it is dark not by contrast, as it would be thoughtlessly said, but by the nerve being somewhat exhausted of its sensibility. This, then, is the first effect we shall remark as arising from the searching motion of the eye.

The refreshing colours of the natural landscape are at no time so pleasing as when reading on a journey, we turn the eye from the book to the fields and woods; the shadows are then deeper—the greens more soothing, and the whole colours are softened. Reynolds observed to Sir George Beaumont that the pictures of Rubens appeared different to him, and less brilliant, on his second visit to the continent; and the reason of the difference he discovered to be that, on the first visit, he had taken notes, and on the second he did not. The alleged reason is quite equal to the effect; but I cannot help imagining that there is some incorrectness in the use of the term brilliant, unless warmth and depth of colouring is meant, for when the eye turns from the white paper to the painting, the reds and yellows must necessarily be deeper. If we look out from the window, and then turn towards a picture, the whole effect is gone—the reflected rays from the picture are too feeble to produce their impression; and if we look upon a sheet of paper, and then upon a picture, the tone will be deeper, and the warm tints stronger, but the lights and shades less distinct. If we place an oil painting without the frame, upon a large sheet of paper, or against a white plastered wall, it is offensively yellow. Here the eye alternately, though insensibly, moving from the white paper or wall to the painting, which is of a deep tone, the browns and yellows are unnaturally strong. We see the necessity or the effect of the gilt frame for such a picture: it does not merely cut off surrounding objects, but it prepares the eye for the colours of the painting—it allows, if I may so express it, the painter to use his art more boldly, and to exaggerate the colours of nature.

Painters proceed by experiment. If they are painting a portrait, they may represent the features by contrasts of lights and shadows with very little colour; but such a portrait is never popular. If they are to represent the features without much contrast of light and shade, they must raise the features by contrasts of colours, and the carnations are necessarily exaggerated; but all this is softened down by throwing a piece of drapery into the picture, the colours of which so prepare the eye that, now looking on the features, that will appear natural, which, but for this art, would have represented an inflamed countenance. The common resource of the painter is to throw in a crimson curtain, or to introduce some flower or piece of dress, that shall lead the eye, by a succession of tints, or, more accurately speaking, shall prepare the eye to receive the otherwise exaggerated colours of the portrait. The eye cast on the red curtain, and then falling on the countenance, sees it as if coloured only with the modesty of nature.

Those who hang pictures, do not place an historical picture, painted

after the manner of the Bolognese school with distinct and abrupt coloured draperies, by the side of a landscape; for the colours of a landscape, to be at all consonant with nature, are weak and reduced to a low tone, by representing that effect, which we observed, of the intervention of the atmosphere. The colours, therefore, would be destroyed by too powerful a contrast. There is a difficulty of deciding what should be the colour of the walls of a gallery, because the pictures are, for the most part, painted on different principles; but generally speaking, the dark subdued red or morone colour brings out the colours of paintings; in other words, if we look on a wall of this colour, and then turn to the picture, the prevailing green and yellow tints will appear brighter.

The "contrast" is used without a definition, or without the actual comprehension of what it means. Now the effect of colours, on being placed together, is produced through the *motion* of the eye, combined with this law of the sensibility of the retina, which we have been adverting to. When we imagine that we are comparing colours, we are really experiencing the effect of the nerve being exhausted, by dwelling on one colour, and made more susceptible of the opposite colour. In coloured drapery, for example, there is such a mixture of all colours reflected from it, although one prevails, that the impression may be greatly modified by what the eye has previously experienced. If the colouring of the flesh be, as the painter terms it, "too warm," it may be made "cold" by rendering the eye insensible to the red and yellow rays, and more than usually susceptible of the blue and purple rays. Every coloured ray from the flesh is transmitted to the eye; but if the eye has moved to it from a yellow or crimson drapery, then the rays of that kind will be, for the moment, lost to the vision, and the colour of the flesh will appear less warm, in consequence of the prevalence of the opposite rays of colour.

It ought to be unsatisfactory to the philosophical student to make use of a term without knowing its full meaning. There has been a great deal said about contrast and harmony in painting, as resulting from certain colours placed together—the idea being that we see these colours at the same time—whereas, the effect, of which we are all sensible, results from alternately looking at the one and at the other. The subject might be pleasantly pursued, but I mean only to vindicate the importance of the motions of the eye to our enjoyment, whether of the colours of art or of nature. There is another subject of some interest, namely, the effect produced upon the retina when the eye is intently fixed upon an object, and is not permitted to wander from point to point. This touches the chiaroscuro of painting; which is not merely the managing of the lights and shadows, but the preserving of the parts of a scene subordinate to the principal object. There is something unpleasant and imperfect, even to the least experienced eye, in a picture in which every thing is

made out—the drapery of every figure, the carving or ornament of every object minutely represented; for these things were never so seen in nature. The true picture, on the other hand, is effective, and felt to be natural, when the eye is at once led to dwell on that principal group, or principal figure, with which it is the artist's intention to occupy the imagination. By fine mastery of his art, and by insensible degrees, the painter keeps down the parts which are removed from the centre; and thus he represents the scene as when we look intently upon an object—seeing that which is near the axis of the eye distinctly—the other objects, as it were, retreating or rising out less and less distinctly, in proportion as they recede from the centre. In the one instance, the artist paints a panorama, where we turn round and have presented before the eye the several divisions of the circle, in each of which the objects are equally distinct; in the other, he paints a picture representing things, not as when the eye wanders from the one part to the other, but where it is fixed with higher interest upon some central object, while the others fall off subordinately.

Looking to our main argument, the proofs of beneficence in the capacities of the living frame, we revert naturally to the pleasures received through this double property of the eye—motion and sensibility; and whilst we perceive that the varieties of light and shade are necessary to vision, we find that the coloured rays are also, by variety, suited to the higher exercise of this sense. They do not all equally illuminate objects, nor are they all equally agreeable to the eye. The yellow, pale green, or Isabella colours, illuminate in the highest degree, and are the most agreeable to the sense; and we cannot but observe, on looking out on the face of nature, that they are the prevailing colours.* The red ray illuminates the least, but it irritates the most; and it is this variety in the influence of these rays upon the nerve that continues its exercise, and adds so much to our enjoyment. We have pleasure from the succession and contrast of colours, independently of that higher gratification which the mind enjoys through the influence of association.

* The astronomer selects a glass for his telescope, which refracts the pale yellow light in the greatest proportion, because it illuminates in the highest degree and irritates the least.

ADDITIONAL ILLUSTRATIONS TO THE CONCLUDING CHAPTER.

I HAVE sometimes thought it possible, that a greatly extended survey of nature may humble too much our conceptions of ourselves; and that this requires to be corrected by the study of things more minute, and in which we are more directly concerned: by dwelling on the perfection of the frame of the animal body and the marvellous endowments of the living properties. When we have formed some estimate of the immensity of the heavenly bodies, we are struck with admiration in following the successive advancement made in the science:—an improvement in the curves of the glasses of the telescope, a new mode of polishing the reflecting surfaces, a change in the chemical composition of the glasses, a more perfect adjustment of their dispersive powers—is followed by the discovery of circle beyond circle of worlds interminably.

We fan the imagination and labour to comprehend the immensity of the creation, and fall back with the impression of the littleness of all that belongs to us: our lives seem but a point of time, compared with the astronomical and geological periods, and we ourselves as atoms, driven about, amidst unceasing changes of the material world.

But it has been shown, that whether we take the animal body as a single machine, or embrace in the survey the successive creation of animals, conforming always to the improving condition of the earth, there is nothing like chance or irregularity in the composition of the system. In proportion indeed as we comprehend the principles of mechanics, or of hydraulics, as applicable to the animal machinery, we shall be satisfied of the perfection of the design: and if anything appear disjointed or thrown in by chance, let the student mark that for contemplation and experiment, and most certainly when it comes to be understood, other parts will receive the illumination, and the whole design stand more fully disclosed.

The extension of knowledge has not necessarily the effect of raising the mind to more consolatory contemplations. We may quote the ancient philosopher in contrast with the modern. The former having nothing in his mind to draw him from observing the just relations of human beings to the world; but on the contrary, seeing everything suited to man or subordinate, thinks of him "as a little God harboured in a humane body." But when by science, and the aid of instruments, or "the ingenuity of the hand," vision is extended to things too remote perhaps, or too minute, to fall within our natural sphere; when instead of the extended plane, and visible horizon of the stable earth, it is thought of as a ball rolling through space, amidst myriads besides, greater than it: the expression is excusable that—"the earth with man upon it does not seem much other than an ant-hill, where some ants carry corn, and some carry their young, and some go empty, and all to and fro, a little heap of dust."

We may consider man, before the lights of modern philosophy had their influence on his thoughts, as in a state more natural; in as much as he yielded unresistingly to those sentiments which directly flow from the objects and phenomena around him. But when that period of society arrived, in which man made natural phenomena the subjects of experiment or of philosophical inquiry, then was there some danger of a change of opinion, not always beneficial to his state of mind. This danger does not touch the philosopher so much as the scholar. He who has strength of mind and ingenuity enough to make investigations into nature, will not be satisfied with the discovery of secondary causes—his mind will be enlarged, and the subjects of his thoughts and aspirations become more elevated. But it is otherwise with those not themselves habituated to investigation, and who learn at second-hand, the result of those inquiries. If such a one sees the fire of heaven brought down into a phial, and the materials compounded, to produce an explosion louder than the thunder, and ten times more destructive, the storm will no longer speak a language to him. Those influences which are natural and just, and beneficently provided, and have served to develope the sentiments of millions before him, are dismissed as things vulgar and to be despised.—Yet with all the pride of newly acquired knowledge, his conceptions embarrass, if they do not mislead him; in short, he has not had that intellectual discipline, which should precede and accompany the acquisition of knowledge.

But a man, possessed of genius of the highest order, may lose the just estimate of himself, from another cause. The sublime nature of his studies may consign him to depressing thoughts. He may forget the very attributes of his mind, which have privileged these high contemplations, and the ingenuity of the hand, which has so extended the sphere of his observation.

The remedy, to such a mind, is in the studies which we are enforcing. The heavenly bodies, in their motions through space, are held in their orbits by the continuance of a power, not more wonderful nor more deserving of admiration, than that, by which a globule of blood is suspended in the mass of fluids:—or by which, in due season, it is attracted and resolved: than that, by which a molecule entering into the compositition of the body, is driven through a circle of revolutions, and made to undergo different states of aggregation; becoming sometime, a part of a fluid, sometime, an ingredient of a solid:—and finally cast out again, from the influence of the living forces.

Our argument in the early part of the volume, has shown man, by the power of the hand (as the ready instrument of the mind) accommodated to every condition through which his destinies promise to be accomplished. We first see the hand ministering to his necessities, and sustaining the life of the individual:—a second stage of his progress, we see it adapted to the wants of society, when

man becomes a labourer and an artificer. In a state still more advanced, science is brought in aid of mechanical ingenuity. The elements which seemed adverse to the progress of society, become the means conducing to it. The seas which at first set limits to nations, and grouped mankind into families, are now the means by which they are associated. Philosophical chemistry has subjected the elements to man's use; and all tend to the final accomplishment of the great objects to which everything, from the beginning, has pointed; the multiplication and distribution of mankind, and the enlargement of the sources of his confort and enjoyment—the relief from too incessant toil, and the consequent improvement of the higher faculties of his nature. Instinct has directed animals, until they are spread to the utmost verge of their destined places of abode. Man too is borne onwards; and although, on consulting his reason, much is dark and doubtful, yet does his genius operate to fulfil the same design, enlarging the sphere of life and enjoyment.

Whilst we have before us the course of human advancement, as in a map, we are recalled to a narrower, and yet a more important consideration: for what to us avail all these proofs of divine power—of harmony in nature—of design—the predestined accommodation of the earth, and the creation of man's frame and faculties, if we are stopped here? If we perceive no more direct relation between the individual and the Creator? But we are not so precluded from advancement: on the contrary, reasons accumulate at every step, for a higher estimate of the living soul, and give us assurance that its condition is the final object and end of all this machinery, and of these successive revolutions.

To this, must be referred the weakness of the frame, and its liability to injury, the helplessness of infancy, the infirmities of age, the pains, diseases, distresses, and afflictions of life—for by such means is man to be disciplined—his faculties and virtues unfolded, and his affections drawn to a spiritual Protector.

THE

CLASSIFICATION OF ANIMALS,

IN

EXPLANATION OF THE TERMS INCIDENTALLY USED IN THE VOLUME.

The Animal Kingdom is arranged in four Divisions:

Division I. *Vertebral Animals:* so called from their possessing a vertebral column or spine.

Division II. *Molluscous Animals:* such as shell-fish, which are of a soft structure, and without a skeleton. *Etym.* mollis, soft.

Division III. *Articulated Animals:* like the worm or insect: they are without a skeleton, but their skins or coverings are divided and jointed. *Etym.* Articulus, dim. a joint.

Division IV. *Zoophytes:* animals believed to be composed very nearly of a homogeneous pulp, which is moveable and sensible, and resembles the form of a plant. *Etym.* ζωον, *zoon*, a living creature; φυτον, *phyton* a plant.

DIVISION I.

The division of vertebral animals is composed of four Classes: viz., 1. Mammalia, animals which suckle their young. *Etym.* mamma, a teat. 2. Aves. *Etym.* avis, a bird. 3. Reptilia, animals that crawl. *Etym.* from a part of the word repo, to creep. 4. Pisces. *Etym.* piscis, a fish.

The first Class Mammalia, is divided into Orders, which are subdivided into Genera, and these are further divided into Species.

We present the principal Orders with familiar examples.

Bimana, man. *Etym.* bis, double; manus, hand.

Quadrumana. *Etym.* quatuor, four; manus, hand. Monkeys, makis or lemurs (*Etym.* lemures, ghosts.) The loris tardigradus (tardus, slow; gradior, to walk) is a species of lemur.

Cheiroptera *Etym.* χειρ, *cheir*, the hand; πτερον, pteron, a wing. The Bats.

Insectivora. *Etym.* insecta, insects; voro, to eat. Hedge-hog; shrew; mole.

Plantigrade. *Etym.* planta, the sole of the foot; gradior, to walk. Bear; racoon.

Digitigrade. *Etym.* digitus, the toe, or finger; gradior, to walk. Lion; wolf; dog; weasel.

Amphibia. *Etym.* αμφι, *amphi*, both; βιος, *bios*, life. Walrus; seal.

Marsupialia. *Etym.* marsupium, a pouch. Kangaroo; opossum.

Rodentia. *Etym.* rodo, to gnaw. Squirrel; beaver; rat; hare.

Edentata. *Etym.* edentulus, toothless: animals without the front teeth. Ai; unau; armadillo; ant-eater; tamandua; megatherium (μεγα, *mega*, great; θηριον, *therion*, a wild beast;) megalonyx (μεγας, *megas*, great; ονυξ, *onyx*, a claw;) ornithorhynchus (ορνιθος; *ornithos*, of a bird; ρυνχος, *rhynchos*, a beak.)

Pachydermata. *Etym.* παχυς, *pachys*, thick; δερμα, *derma*, skin. Rhinoceros, elephant: mammoth: mastodon (μαστος *mastos*, a nipple; οδων, *odon*, a tooth;) tapir; horse; couagga.

Ruminantia. *Etym.* ruminatio, chewing the cud. Camel; giraffe; deer; goat; cow; sheep.

Cetacea. *Etym.* cetus, a whale. Dolphin; whale; dugong.

Second Class. *Aves*, or *Birds*.

Accipitres. *Etym.* accipiter, hawk. Vulture; eagle; owl.

Passeres. *Etym.* passer, a sparrow. Lark; thrush; swallow; crow; wren.

Scansores. *Etym.* scando, to climb. Parrot; wood-pecker; toucan.

Gallinæ. *Etym.* gallina, a hen. Peacock; pheasant; pigeon.

Grallæ. *Etym.* grallæ, stilts. Ostrich; stork; ibis; flamingo.

Palmipedes. *Etym.* palma, the palm of the hand; pes, foot. Swan; pelican; gull.

Third Class. *Reptiles*.

Chelonia. *Etym.* χελυς, *chelys*, a tortoise. Tortoise; turtle.

Sauria. *Etym.* σαυρα, *saura*, a lizard. Crocodile; alligator, chameleon; dragon; pterdoctyle (πτερον, *pteron*, a wing; δακτυλυς, *dactylus*, a finger;) ichthyosau-

rus (ιχθυς, *ichthys*, a fish; σαυρα, *saura*, a lizard;) plesiosaurus (πλεσιον, *plesion*, near to; σαυρα, *saura*, a reptile;) megalasaurus (μεγαλε, *megale*, great; σαυρα, *saura*, a reptile;) iguanadon.

Ophidia. *Etym.* οφις, *ophis*, a serpent. Boa; viper.

Batrachia. *Etym.* βατραχος, *batrachos*, a frog. Frog; salamander; proteus.

Fourth Class. *Fishes.*

Chondropterygii. *Etym.* χονδρος, *chondros*, gristle; πτερυξ, *pteryx*, the ray of a fin. Ray; sturgeon; shark; lamprey; ammocete (αμμος, *ammos*, sand; κητος, *cetos*, a fish.)

Piectognathi. *Etym.* πλεκο, *pleco*, to join; γναθος, *gnathos*, the jaw. Sun-fish; trunk-fish.

Lophobranchi. *Etym.* λοφος, *lophos*, a loop; βραγχια, *branchia*, the gills. Pipe-fish; pegasus.

Melacopterygii. *Etym.* μαλακος, *malakos*, soft; πτερυξ *pteryx*, the ray of a fin. Salmon; trout; cod; herring; remora.

Acanthopterygii. *Etym.* ακανθα, *acantha*, a thorn; πτερυξ, *pteryx*, the ray of a fin. Perch; sword-fish; mackarel; lophius piscatorius (λοφια, *lophia*, a pennant; piscator, a fisher;) chætodon rostratus (χαιτε, *chæte* hair; οδων, *odon*, a tooth; rostratus, beaked;) zeus ciliaris (cilium, an eye-lash.)

DIVISION II.

MOLLUSCOUS ANIMALS.

1st. Class. Cephalopoda. *Etym.* κεφαλε, *cephale*, the head; ποδα, *poda*, the feet. Animals which have their organs of motion arranged round their head.

This class includes Sepia, or Cuttle-fish. Argonauts (Αργω, the ship Argo, ναυτης, *nautes*, a sailor.) Nautilus, (ναυτης, *nautes*, a sailor.) Ammonite, an extinct Cephalopode which inhabited a shell resembling that of the Nautilus; coiled like the horns of a ram or of the statues of Jupiter Ammon; whence the name. Belemnites: also extinct: the shell is long, straight, and conical (βελεμνον, *belemnon*, a dart.) Nummulites: likewise extinct. Whole chains of rocks are formed of its shells. The pyramids of Egypt are built of these rocks, (nummus, a coin.)

2d Class. Pteropoda. *Etym.* πτερον, *pteron*, a wing; ποδα, *poda*, feet; having fins or processes resembling wings on each side of the mouth.

The Clio Borealis, which abounds in the North Seas, and is the principal food of the whale.

3d Class. Gasteropoda. *Etym.* γαστερ, *gaster*, the stomach; ποδα, *poda*, the feet. Animals which move by means of a fleshy apparatus placed under the belly.

The snail; slug; limpet.

4th Class. Acephala. *Etym. a*, α, without; κεφαλε, *cephale*, the head. Molluscous animals without a head.

The oyster; muscle.

5th Class. Brachiopoda. *Etym.* βραχιον, *brachion*, the arm; ποδα, *poda*, the feet. Animals which move by means of processes like arms.

Lingula; terebratula.

6th Class. Cirrhopoda. *Etym.* cirrus, a lock or tuft of hair; ποδα, *poda*, the feet.

Balanus; barnacle anatifera, (anas, a duck, fero, to bring forth.)

DIVISION III.

ARTICULATA.

1st Class. Annelides, or Vermes. *Etym. Annellus*, a little ring; *vermis*, a worm.

Leech; sea-mouse; earth-worm; sand-worm; tubicolæ, (tubus, a tube, colo, to inhabit;) worms which cover themselves by means of a slimy secretion that exudes from their surfaces, with a case of small shells and pebbles, like the caddis-worm, or with sand and mud.

2d Class. Crustacea. Animals which have a shelly crust, covering their bodies.

The crabs; shrimps; lobsters.

3d Class. Arachnida. *Etym.* αραχνης, *arachnes*, a spider.

Spiders; aranea scenica, or saltica; the leaping spider; the scorpion spider; the mite.

4th Class, Insecta. They are divided into insects which are without wings and those which have them: and these are further subdivided according to the peculiarities of the wings.

Aptera (α, *a*, without; πτερον, *pteron*, a wing.) Centipede (having a hundred feet;) louse; flea.

Coleoptera (κολεος, *coleos* a sheath or scabbard, πτερον, a wing,) insects which have their wings protected by a cover, as the beetle, corn-weevil. *Orthoptera* (ορθος, *orthos*, straight, πτερον,) as the locust, grass-hopper. *Hemiptera* (ημισυ, *hemisu*, half, πτερον,) insects which have one half of their wings thick and coriaceous, and the other membranous; such as a bug, tick, fire-fly. *Neuroptera* (νευρον *neuron*, a nerve, πτερον,) dragon-fly; ant-lion; ephemera. *Hymenoptera* (υμεν, *hymen*, a membrane, πτερον,) the bee; wasp; ant. *Lepidoptera* (λεπις, *lepis*, a scale, πτερον,) moth; butter-fly. *Rhipiptera* (ριπις, *ripis*, a fan, πτερον,) xenos; stylops. *Diptera* (δις, *dis* double, πτερον,) house-fly; gnat.

DIVISION IV.

ZOOPHYTES.

Echinodermata (*Etym.* εχινος, *echinos*, a hedgehog; δερμα, *derma*, the skin,) the star-fish; sea urchin. *Entoza* (εντος, *entos*, within; ζαω *zao*, to live,) tænia hydatia. *Acalephæ* (ακαληφη, *acalephe*, a nettle,) medusa; polypi (containing much sap; sea-anemone; hydra; tubipora (inhabiting tubes;) sertularia; cellularia; flustra; coralline; sponge. *Infusoria* (found in infusions or stagnant water,) monas; vibrio; proteus.

THE END.